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Research and
Special Programs
Administration

OPA 90
Programmatic Regulatory Assessment (PRA)

BENEFIT, COST, AND COST EFFECTIVENESS OF ELEVEN MAJOR RULEMAKINGS OF THE OIL POLLUTION ACT OF 1990

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ACRONYMS

ACOE	U.S. Army Corps of Engineers
BNSR	Barrels of oil not spilled or spilled and removed from the water
CFR	Code of Federal Regulations
COR	Certificates of Registry
COTP	Captain of the Port
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DSC	Deck Spill Control
EEZ	Exclusive Economic Zone
E&P	Equipment and Personnel
ERV	Escort Response Vessel
FBI	Federal Bureau of Investigation
FR	*Federal Register*
GNP	Gross National Product
GT	Gross Tonnage
IMO	International Maritime Organization
MMD	Merchant Mariners' Documents
MODU	Mobile Offshore Drilling Unit
MSIS	Marine Safety Information System
MTR	Marine Transportation Related
NPFC	National Pollution Funds Center
NRC	National Research Council
NRDA	Natural Resource Damage Assessment
OMB	Office of Management and Budget
OPA 90	Oil Pollution Act of 1990
PNS	*Port Needs Study* (USCG, 1991)
PRA	Programmatic Regulatory Assessment
PRAAM	Programmatic Regulatory Assessment Accounting Model
PWS	Prince William Sound (Alaska)
RA	Regulatory Assessment
SCC	Spill Source Control and Containment
TAPS	TransAlaska Pipeline System
TPV	Total Present Value
USCG	United States Coast Guard
VRP	Vessel Response Plan

PREFACE

The United States Coast Guard (USCG) promulgated a wide range of new regulations directed at oil spill prevention, mitigation, cleanup, and liability in response to broad mandates contained in the Oil Pollution Act of 1990 (OPA 90). To facilitate rapid rulemaking, the Coast Guard divided OPA 90 requirements into stand-alone rulemaking projects. Economic, environmental, small entity, and information collection impacts were analyzed appropriately for each of these projects. When the Coast Guard completed the majority of the OPA 90 rules, it joined with the Volpe National Transportation Systems Center (Volpe Center) to prepare a Programmatic Regulatory Assessment (PRA). The purpose of the PRA is to evaluate the combined benefit, cost, and cost effectiveness of OPA 90 regulations published by the Coast Guard, using a core group of 11 rules as a proxy for the entire suite of rules.

This document presents—

- An overview of OPA 90 and the PRA, including issues addressed, individual rulemaking efforts undertaken throughout the 1990s, and a conceptualization of the analyses undertaken in this document
- An oil spill baseline for 1996–2025 based on historic data and expert opinion
- Benefit, cost, and cost effectiveness estimates for OPA 90 using 11 primary rules

TECHNICAL APPENDICES, an accompanying document, presents extensive detail of the analyses performed for the PRA as well as other important supplemental information.

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EXECUTIVE SUMMARY

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Background

The United States Coast Guard (USCG) promulgated a wide range of new regulations directed at oil spill prevention, mitigation, cleanup, and liability in response to broad mandates contained in the Oil Pollution Act of 1990 (OPA 90). To facilitate rapid rulemaking, the Coast Guard divided OPA 90 requirements into stand-alone rulemaking projects. Economic, environmental, small entity, and information collection impacts were analyzed appropriately for each of these projects. When the Coast Guard completed the majority of the OPA 90 rules, it joined with the Volpe National Transportation Systems Center (Volpe Center) to prepare a Programmatic Regulatory Assessment (PRA). The purpose of the PRA is to evaluate the combined benefit and cost effectiveness of OPA 90 regulations published by the Coast Guard, using a core group of 11 rules as a proxy for the entire suite of rules.

This document presents—

- An overview of OPA 90 and the PRA, including issues addressed, individual rulemaking efforts undertaken throughout the 1990s, and a conceptualization of the analyses undertaken in this document
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TECHNICAL APPENDICES, an accompanying document, presents extensive detail of the analyses performed for the PRA as well as other important supplemental information.

Methods

This PRA contains an innovative analytical approach to assess a core group of rules within OPA 90 that targets the multiple sources and causes of oil spills. Accounting for the simultaneous and overlapping effects of OPA 90 rules required a complex mathematical procedure. The assessment process, explicit assumptions, innovative computational procedures, and accounting software developed for this PRA provided the Coast Guard with a consistent means of estimating the overall benefits of the OPA 90 regulations as well as the relative cost effectiveness—or marginal benefit—provided by each rule. This PRA—

- Defines a common assessment period, an oil transport traffic forecast, a projected spill baseline, and a consistent costing method

- Applies a rigorous procedure for obtaining expert opinions on the potential effectiveness of each individual rule with respect to its intended target

- Applies a method to account for multiple rules addressing multiple outcomes without double counting the effects

- Applies a standardized Total Present Value (TPV) computation to assess the benefits and costs of OPA 90 rules

Two expert panels convened to assist the Coast Guard and Volpe Center in developing oil spill baselines and effectiveness factors for individual rules. The panel workshops encouraged extensive discussion and exchange of public- and private-sector opinions and provided an excellent source of information to ensure consistency and comprehensiveness.

Results

This PRA addresses two questions—

1) What is the overall benefit[1] and overall cost effectiveness of a core group of Coast Guard regulations within OPA 90?

2) What is the relative contribution of each regulation to these overall values?

This analysis estimates that a core group of rules results in a 67 percent reduction in total oil spillage. The analysis also estimates that overall cost effectiveness for the assessment period is $8,657/BNSR (TPV in 1996 constant dollars).[2] Additionally, the analysis has estimated the marginal benefit (i.e., the relative contribution that an individual rule has toward the overall benefit) for each of the rules in the core group.

This PRA aggregates and compliments the cost and benefit analyses in regulatory assessments (RAs) conducted throughout the 1990s for individual OPA 90 rules. Consistent with previous

[1] Benefits are measured in an expression of effectiveness that is "barrels of oil not spilled, or if spilled, removed from the water." Dollar values are not assigned to environmental damages averted by OPA 90. During the early 1990s, a rulemaking to codify natural resource damage assessment (NRDA) methodologies trailed the Coast Guard's OPA 90 rulemaking thrust. NRDAs as subsequently codified are event-specific, post-incident technologies, which require consideration of key variables that include, but are not limited to, specific location, season, air temperature, water temperature, wind velocity, and spill composition. In our view, monetizing oil pollution prevention benefits "before the fact" for national or even regional rulemakings remains sufficiently unreliable and assailable to warrant continued use of the effectiveness expression until a generalized method of monetization becomes widely accepted.

[2] BNSR— barrels of oil not spilled, or if spilled, removed from the water.

findings, this assessment concludes that while all OPA 90 rules reduce the total quantity of oil spilled by water transport systems, some rules have a greater effect than do others. For example, the rule establishing financial responsibility contributes approximately 60 percent to the overall benefits (as measured in BNSR). In contrast, the rule for deck spill control contributes less than 1 percent to the overall benefit.

The marginal benefit and marginal cost effectiveness estimates for each rule in the core group provide good approximations of the relative cost effectiveness of these core rules. This PRA confirms earlier judgements about cost effectiveness made in individual RAs.

A sensitivity analysis in this PRA shows that when core-group OPA 90 rules are ranked in order of their respective marginal cost effectiveness, uncertainties about key parameters have little effect on final results. The rank order of rules by their marginal values remains relatively constant among the alternative cases analyzed.

Finally, a Coast Guard analysis determines that 83 of the possible 2,047 combinations of the 11 rules within the core group are optimal—the combination of rules maximizes possible benefit while minimizing possible costs. The combination of all 11 rules in the core group is one of these optimal points and maximizes the number of BNSR in a cost-effective manner.

OPA 90 AND THE

PROGRAMMATIC REGULATORY ASSESSMENT

1. INTRODUCTION

Background

The United States Coast Guard (USCG) promulgated a wide range of new regulations directed at oil spill prevention, mitigation, cleanup, and liability in response to broad mandates contained in the Oil Pollution Act of 1990 (OPA 90). To facilitate rapid rulemaking, the Coast Guard divided OPA 90 requirements into stand-alone rulemaking projects. Economic, environmental, small entity, and information collection impacts were analyzed appropriately for each of these projects. When the Coast Guard completed the majority of the OPA 90 rules, it joined with the Volpe National Transportation Systems Center (Volpe Center) to prepare a Programmatic Regulatory Assessment (PRA). The purpose of the PRA is to evaluate the combined benefit, cost, and cost effectiveness of OPA 90 regulations published by the Coast Guard, using a core group of 11 rules as a proxy for the entire suite of rules.

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TECHNICAL APPENDICES, an accompanying document, presents extensive detail of the analyses performed for the PRA as well as other important supplemental information.

Purpose

The purpose of this document is to—

- Assess the status of OPA 90 rules and supporting studies and identify cost and benefit estimates contained in individual regulatory assessments (RAs) for each rule
- Develop an appropriate method to assess the overall impact of OPA 90 rules consistent with USCG and Office of Management and Budget (OMB) preferences for regulatory analysis
- Determine the baseline oil spillage that would occur during the PRA assessment period (1996–2025) if a core group of 11 OPA 90 rules were not in place

- Estimate the assessment-period effectiveness of the core group of OPA 90 rules on oil spills from various sources (expressed in barrel of oil not spilled or spilled and removed from the water)

- Estimate the assessment-period costs of the core group of OPA 90 rules (expressed in 1996 dollars)

- Estimate the cost effectiveness of the core group of OPA 90 rules (expressed in 1996 dollars per barrel of oil not spilled or spilled and removed from the water)

- Conduct sensitivity analyses that change the parameters of the primary analysis (reference case)

- Analyze the 2,047 possible combinations of the 11 core group rules within OPA 90 and assess their cost effectiveness

Scope

The scope of the PRA is limited to those rules under OPA 90 Titles IV and V. These rules focused on—

- Oil spill prevention and mitigation

- Oil spill removal and cleanup

- Licensing of mariners

- Financial responsibility of vessel owners and operators

The PRA assesses rules applying to equipment and technology on U.S. and foreign-flagged vessels operating in U.S. waters. Crews on foreign vessels are excluded from the licensing provisions of OPA 90, but they are covered in rules established by their respective governments. For purposes of this PRA, foreign regulations are assumed to make the same contribution to benefits and costs because although there is no direct, explicit U.S. authority over foreign crews, foreign governments reciprocally enforce OPA 90 rules in their waters.

This analysis covers a 30-year period, 1996–2025. This period was chosen because—

- Harmonizing the analysis periods in the various RAs greatly simplified the assessment process for several regulations, in which most effective dates ranged from 1990 to 1995. The

research team believed this simplification would not significantly affect results and would avoid the complicated and costly approach of using different start dates for each rule.

- A start date of 1996 allowed the research team to analyze historic oil spill data through 1995, the most recent year available at the time the RAs were written, with a seamless transition into the forecast period.

- A 30-year period through 2025 permitted the research team to project estimates well beyond the final phase-in of all OPA 90 provisions, which will occur around 2015.

The overall cost to U.S. government agencies and to domestic and foreign industries operating in U.S. waters is estimated in 1996 constant dollars. The overall benefit is estimated as the number of barrels of oil not spilled or the number of barrels of oil spilled and removed from the U.S. marine environment, or BNSR.[3] The Total Present Value (TPV) of 30-year costs and benefits are estimated by discounting to 1996 at a 7 percent discount rate. The impact of OPA 90 is presented as the overall cost effectiveness of the core group of OPA 90 rules, expressed in dollars per barrel of oil not spilled or spilled and recovered ($/BNSR).

[3] May include U.S. Navigable Waters (defined in 33 CFR 2.05-25) and the Exclusive Economic Zone (EEZ) (defined in 33 CFR 2.05-35), depending on the specific regulation.

2. OPA 90

Sources of Oil Spills

USCG has promulgated, or is in the process of promulgating, approximately 45 rules that address Titles IV and V of OPA 90.

OPA 90 Title IV and V rules are intended to—

- Reduce the potential for future accidents or failures[4] of oil-carrying vessels or oil facilities that could result in oil spills
- Take immediate control of spills that do occur
- Remove spilled oil before substantive damage to the marine environment occurs

OPA 90 rules address many possible sources of oil spills within the waterborne oil transportation system. The first step in the analytical process, therefore, was to identify and separate the potential sources of oil spills. In this analysis, sources of oil spills are grouped as follows.

- Oil-laden tankers underway
- Oil-laden barges underway
- Tanker lightering operations
- All offshore facilities[5] and onshore marine transportation-related facilities[6]

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[4] "Accident" and "failure" are used interchangeably in this report.

[5] Title I Oil Pollution Liability and Compensation, Section 1001, Definitions, Part (9) of OPA 90 states "'facility' means any structure, group of structures, equipment, or device (other than a vessel) which is used in one or more of the following purposes: exploring for, producing, storing, handling, transferring, processing, or transporting oil."

[6] Title IV, Subtitle B, Removal, Section 4202, National Planning and Response System, (a) in general, Part (5), of OPA 90 adds to the end of the Federal Water Pollution Control Act (33 U.S.C. 1321 (j)) a requirement of tank vessel and facility response plans that applies to all owners of any tank vessel or any offshore facility as well as to all owners of certain onshore facilities. More specifically, it applies to "...[a]n onshore facility that because of its location, could reasonably be expected to cause substantial harm to the environment by discharging into or on the navigable waters, adjoining shorelines, or the exclusive economic zone."

A fifth spill source, bunker fuel tanks, is not a separate source in this PRA, although some OPA 90 rules address the removal of *any* oil spilled on navigable waters, including bunker fuel spills. Bunker tanks were not included primarily because there existed no statutory authority in OPA 90 for pollution prevention measures to be extended to bunker fuel tanks.

Overview of OPA 90 Rules

Title IV of OPA 90 addresses prevention and removal of oil spills within U.S. waters. Prevention addresses causes of oil spills or conditions, situations, or incidents that precede oil spills. For example, Title IV rules address—

- Improved vessel structural standards
- Improved pilotage, vessel movement systems, and tanker navigation safety standards (including escorts)
- Improved vessel manning standards
- Requirements for tank overfill or pressure monitoring devices
- Standards for the revocation of certificates and privileges that permit the operation of vessels and equipment used to transport oil
- Imposition of financial responsibility and penalties
- Improved removal of oil spilled into the marine environment given a casualty or failure

Title V of OPA 90 addresses provisions specific to Prince William Sound (PWS), Alaska. These provisions establish an institute to conduct research and carry out education and demonstration projects to better handle oil spills in the Arctic and Subarctic marine environment and to assess, document, and better understand the long-range effects of the 1990 *Exxon Valdez* oil spill. These provisions also establish advisory councils and committees, terminal and tanker oversight and monitoring standards, and equipment and personnel requirements under tank vessel and facility response plans. Appendix A presents the rules within the scope of this PRA.

RAs were prepared for 18 of the rules within the scope of this PRA. Executive Order 12866, *Regulatory Planning and Review* (September 30, 1993) states that "Each agency shall assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its cost…Each agency shall base its decisions on the best reasonably obtainable scientific, technical, economic, and other information concerning

the need for, and consequences of, the intended regulation." Executive Order 12866 is reproduced in Appendix K.

Types of rules associated with oil spill prevention, mitigation, removal, cleanup, and enforcement are divided into six categories—

1) **Structural and Equipment Failures**—Prevent marine oil spills that can result from structural failures of tankers and tank barges or offshore and onshore facilities. Oil spills can also result from failures in equipment used to transfer oil.

2) **Vessel Casualties**—Prevent cargo tank oil spills and bunker fuel spills that can result from navigational or equipment failures leading to groundings, collisions, and rammings. Requirements may include escort vessels for certain single-hull vessels, use of autopilot, and navigational safety equipment for towing vessels.

3) **Operational Failures**—Prevent oil spills that can result from overfilling cargo tanks or operational failures while lightering tankers.

4) **Oil Spill Cleanup**—Address the cleanup of oil spills to minimize the total amount that is discharged into, and remains in, the environment in the event of an oil spill.

5) **Mariners' Certification and Licensing**—Raise the level of performance of mariners by denying authority to serve on a crew for those personnel whose competence and behavior fails to comply with specified standards. Rules that allow investigation of criminal records for crewmembers may ensure that competent and conscientious people are in control of tankers, barges, and associated equipment.

6) **Financial Responsibility of Vessel Owners and Operators**—Influence oil spills by creating an incentive for compliance with the other rules.

Rules with Regulatory Assessments

Costs and benefits have been extracted for 19 rules with RAs. Table 2-1 summarizes the RAs in each of the six categories of rules. The Coast Guard did not prepare RAs for 14 rules within the scope of this PRA, as the specific nature of the regulatory action did not warrant an RA.

Table 2-1
OPA 90 Rules, Titles, Descriptions, and RAs

Docket Number	Title	Description	RA
Structure and Equipment			
90-051	Establishment of Double Hull Requirements for Tank Vessels	With certain exceptions, required all newly constructed tank ships and barges navigating in U.S. waters to be built with double hulls. Existing tank vessels without double hulls must be phased out over a 25-year period.	*Interim Regulatory Assessment for the Oil Pollution Act of 1990 Titles IV and V*, prepared by Temple Barker and Sloane, Inc., Oct. 1991
91-045 S	Structural Measures for Existing Single-Hull Tank Vessels	The Coast Guard considered several structural and structure-related options for existing single hull tank vessels over 5,000 gross tons. Based on the analyses, the Coast Guard determined that there are no structural measures that are both technologically and economically feasible for these vessels. Thus, no structural measures regulation is in force.	*Regulatory Assessment of Structural Measures for Existing Single-Hull Tankers*, prepared by ICF Kaiser, July 1995
91-209	Requirements for Longitudinal Strength, Plating Thickness, and Periodic Gauging for Certain Tank Vessels	Proposed standards for minimum longitudinal strength and plate thickness for tank vessels that carry oil and required periodic gauging of these vessels after they reach the age of 30 years. The purpose of the regulation was to reduce the likelihood of oil spills from structural failure.	*Final Regulatory Assessment and Regulatory Flexibility Analysis*, prepared by USCG, July 1993
Vessel Casualties			
91-202	Escorts for Certain Tankers (Prince William Sound, Puget Sound, and other U.S. waters)	Required two escort vessels for single hull tankers larger than 5,000 gross tons transporting oil in bulk in Prince William Sound, Alaska and Puget Sound, Washington.	*Final Assessment for Regulations Implementing Section 4116 (c) of the OPA 90, "Escort Vessels for Certain Tankers,"* prepared by USCG, June 1994

Table 2-1 (continued)
OPA 90 Rules, Titles, Descriptions, and RAs

Docket Number	Title	Description	RA
Operation Failures			
90-071a	Overfill Devices	Supplemented mandated conduct for monitoring oil transfer operations and required overfill warning devices.	*Regulatory Assessment and Initial Regulatory Flexibility Analysis*, prepared by USCG, Nov. 1993
91-045 L	Emergency Lightering Equipment and Advance Notice of Arrival Requirements for Existing Tank Vessels without Double Hulls	Required existing single hull tank vessels of 5,000 gross tons or more to carry certain emergency lightering equipment on board.	*Regulatory Assessment for Emergency Lightering Equipment and Advance Notice of Arrival Requirements for Existing Tank Vessels without Double Hulls*, prepared by USCG, May 1994
91-045 O	Operational Measures to Reduce Oil Spills from Existing Tank Vessels without Double Hulls	Decreased the likelihood of a vessel casualty and the amount of oil outflow after a casualty. Rule is effective until 2015 when single hull tank vessels will have been phased out.	*Regulatory Assessment*, prepared by USCG, June 1996
93-081	Designation of Lightering Zones	Established lightering zones, ecologically sensitive areas, the use of industry guidelines, weather and sea state restrictions, and work-hour limitations.	*Final Regulatory Assessment*, prepared by USCG, May 5, 1995
Oil Spill Cleanup			
90-068 DSC	Discharge Removal Equipment and Inspection for Vessels Carrying Oil—Deck Spill Control (DSC)	Required all vessels that carry oil as cargo and that operate in U.S. waters to carry on-board deck spill control and removal equipment. Rule divided into two parts to facilitate analysis of effectiveness. The first part (designated by suffix DSC) pertains to coamings, portable pumps, sorbents, cleaning equipment and protective clothing, waste oil disposal applicable to deck spills.	*Discharge Removal Equipment Regulatory Assessment*, prepared by Volpe Center, May 1993
90-068 SCC	Discharge Removal Equipment and Inspection for Vessels Carrying Oil—Source Control and Containment (SCC) of Spills other than Deck Spills	This is the second part of rule 90-068 (designated by the suffix SCC), which pertains to all equipment required to be carried on board to control any oil spill at the source and to limit the quantity of oil that enters the water.	*Discharge Removal Equipment Regulatory Assessment*, prepared by Volpe Center, May 1993
91-034 VRP	National Planning and Response System: Tank Vessel Response Plans (Oil)	Expected to influence oil outflow volumes when an incident occurs through spill preparedness, response management, and removal of spilled oil from the water.	*Interim Regulatory Assessment For Vessel Response Plans*, prepared by Mercer Management Consulting, March 1993

Table 2-1 (continued)
OPA 90 Rules, Titles, Descriptions, and RAs

Docket Number	Title	Description	RA
Oil Spill Cleanup (continued)			
91-034 E&P	Equipment and Personnel Requirements under Tank Vessel and Facility Response Plans (PWS/TAPS)	Required the TransAlaska Pipeline System (TAPS) vessel and facility response plans to include pre-positioned response equipment. It also established oil spill response organization practice exercises and equipment inspections. This rule was formerly listed as rule 91-221.	*Preliminary Assessment*, Apr. 1992, *Regulatory Assessment*, Nov. 1992, and *Interim Final Regulatory Assessment for the OPA 90 Section 5005 Equipment and Personnel Requirements Under Vessel Response Plans for Tank Vessels Operating in Prince William Sound*, prepared by Volpe Center, Jan. 1993
91-036	National Planning and Response System: Facility Response Plans (Oil)	Required the owner or operator of a facility that poses "substantial harm" to the environment to prepare and submit an oil spill response plan.	*Regulatory Assessment of the U.S. Coast Guard Interim Final Rule on Facility Response Plans*, prepared by ICF, Inc., Dec. 1992
91-235	National Planning and Response System: Facility Response Plans (Hazardous Substances)	Required owners or operators of onshore marine transportation-related facilities to submit a response plan for a worst-case discharge of hazardous substances.	*Regulatory Assessment* prepared by Volpe Center and USCG
91-236	National Planning and Response System: Tank Vessel Response Plans (Hazardous Substances)	Required owners or operators of tank vessels carrying hazardous substances to submit a response plan for a worst-case discharge of hazardous substances.	*Regulatory Assessment* prepared by Volpe Center and USCG
Mariners' Certification and Licensing			
91-211	Renewal of Certificates of Registry, Renewal of Merchant Mariners' Documents, Termination of Existing Licenses, Certificates, and Documents	Established renewal requirements and ways to obtain Certificates of Registry and Merchant Mariners' Documents.	*Five Year Term of Validity for Certificates of Registry and Merchant Mariners' Documents; Final Regulatory Assessment*, prepared by USCG, Aug. 1994
91-212	Criminal Record Reviews in Renewals of Licenses and Certificates of Registry; Access to National Driver Register	Required Coast Guard to search for any past criminal activity (of Merchant Mariners) for each applicant of a license, certificate of registry, or Merchant Marine Document (issuance and renewal).	*Access to National Driver Register and Criminal Record Review for Issuing Licenses, Certificates of Registry, and Merchant Mariners' Documents; Regulatory Assessment*, prepared by USCG, Feb. 1994

Table 2-1 (continued)
OPA 90 Rules, Titles, Descriptions, and RAs

Docket Number	Title	Description	RA
Mariners' Certification and Licensing (continued)			
91-223	Review of Alcohol and Drug Abuse in Issuing Licenses and Certificates of Registry; Review of Alcohol and Drug Abuse in Issuing Merchant Mariners' Documents	Promoted a drug-free maritime workplace and safe vessel operations by identifying applicants who have a record of abuse.	*Applying for Issuance of Licenses, Certificates of Registry or Merchant Mariners' Documents*; *Regulatory Assessment*, prepared by USCG, Sept. 1994
Financial Responsibility of Vessel Owners and Operators			
91-005	Financial Responsibility for Water Pollution Civil Penalties (Vessels)	Addressed financial responsibility and imposed penalties for failure to comply with Section 1016 of OPA 90.	*Responsibility for Water Pollution (Vessels)*, prepared by USCG, March 31, 1994

RA Benefit Estimates

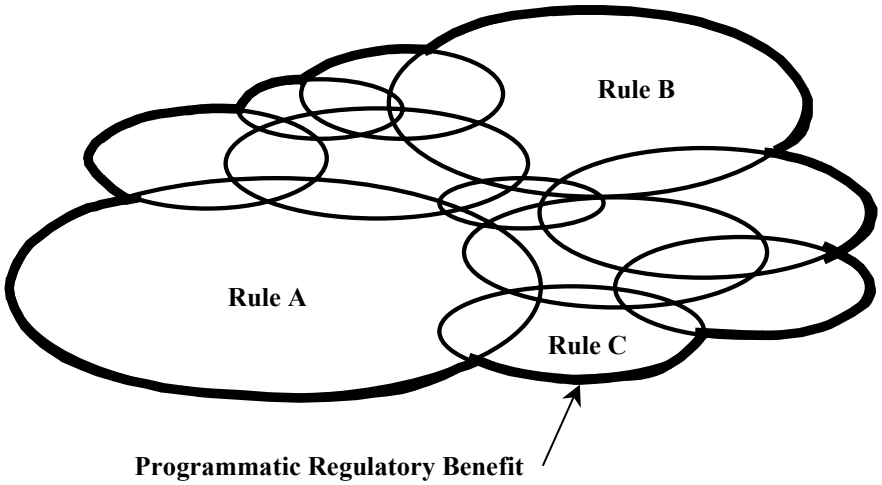
For each rule in its scope, the PRA estimates the reduction in total quantity of oil spilled and the spilled quantity remaining in the water for each spill source. Also, in order to eliminate double counting of benefits among the rules, the PRA estimates each rule's effect on each event in the accident and spill chain of events. Five of the RAs provide detailed benefit data (90-051, 91-071a, 91-034 VRP, 91-034 E&P, and 91-045 S). Additionally, expert panels developed the effectiveness (benefit) factors for each of the 11 rules selected for analysis in this PRA (see Chapter 4).

3. INTERACTIONS OF RULES AND ORDERS OF EFFECTS

Interactions of OPA 90 Rules

OPA 90 rules are not mutually exclusive and do not result in independent benefits—the overall effectiveness of the OPA 90 rules combined will not be the sum of the effectiveness of each individual rule when considered in isolation. Summing individually estimated benefits, or effects, of each rule would result in considerable double counting and would overestimate the benefits of OPA 90. Figure 3-1 illustrates this overlapping concept. The individual ovals represent the individual benefit or individual effectiveness of each rule when considered in isolation from all other rules. The area outlined in bold represents the total overall benefit—or programmatic regulatory benefit—of all rules taken together. In this analysis, the effects of a particular rule must be adjusted downward to account for overlapping effects from other rules.

Figure 3-1
Overlapping Effects and Programmatic Regulatory Benefit of OPA 90 Rules

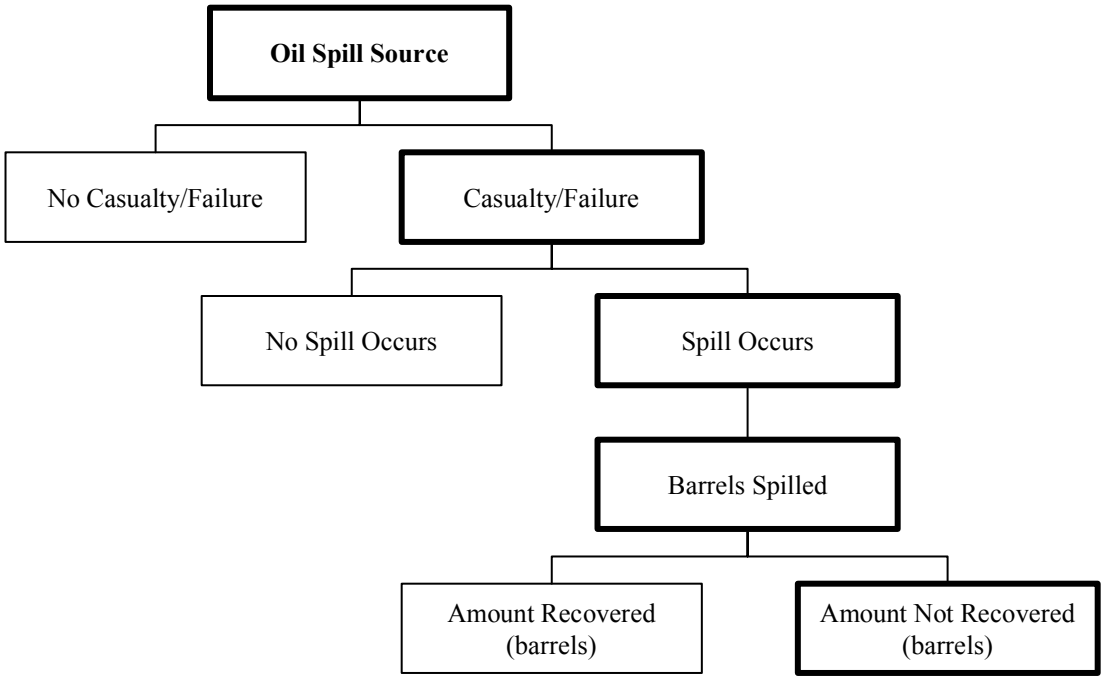


The chain of causal events leading to an oil spill can be displayed in an "event tree."[7] Through an event tree, we can understand the interactions and dependencies of multiple rules on causal events as well as the amount of oil that would enter and damage the marine environment if the event were to occur. Effects that rules have on each branch of the tree must be estimated. A single event tree with all spill sources, estimates of their percent shares of oil transported or stored, and causal chains of events for each rule would be too complex; therefore, separate event trees were employed. Figure 3-2 displays a representative oil spill event tree. After analyzing

[7] This analysis is not a fault tree analysis. A fault-tree approach would examine every possible event that might result in an accident and spill and would estimate events' probabilities of occurring separately. Event trees presented in this PRA are for heuristic purposes only.

each event tree and estimating respective benefits and costs, the sum of the results from all the event trees was derived from the corresponding branches of each tree.

Figure 3-2
Typical Spill Event Tree



Effects of OPA 90 Rules

The Volpe team grouped rules by four "orders of effectiveness" (i.e., how rules affect oil spill sources) to expedite analysis and to avoid double counting benefits. Orders of effectiveness are—

- **First order**—Rule lowers, by some percentage, the likelihood of an accident or failure involving oil transportation or a storage facility (i.e., a spill source)

- **Second order**—Rule lowers, by some percentage, the probability that a spill occurs if an accident or failure occurs

- **Third order—**Rule lowers, by some percentage, the expected quantity of oil spilled if a spill occurs

- **Fourth order**—Rule lowers, by some percentage, the expected quantity of spilled oil that would remain (cannot be removed before damage occurs) in the environment if a spill occurs

Some rules have more than one order of effectiveness. For example, a rule may simultaneously lower the probability of an accident, lower the probability of a spill, lower the expected quantities of spilled oil, and lower the amount of oil remaining in the water to damage the marine environment. Figure 3-3 illustrates the orders of effectiveness within the oil spill event tree.

Figure 3-3
First, Second, Third, and Fourth Order Effects of OPA 90 Rules

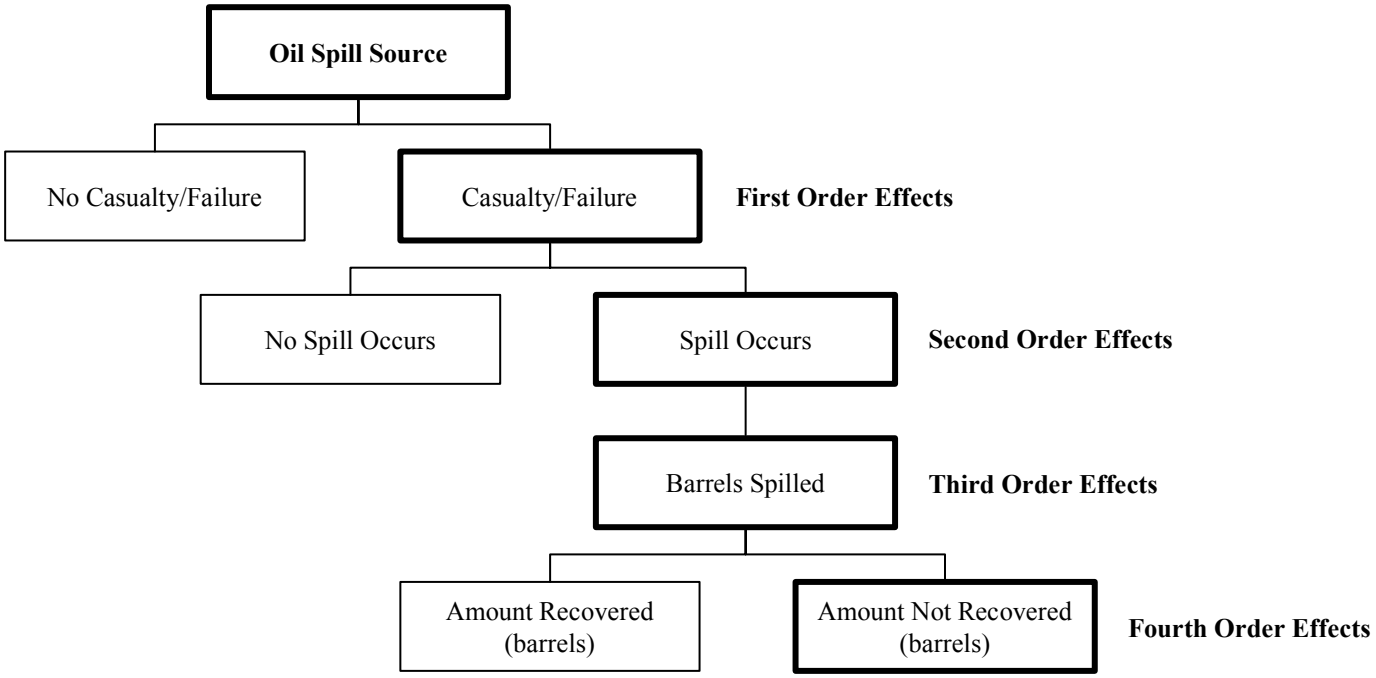


Table 3-1 presents a matrix of 33 OPA 90 rules within the scope of this PRA and their orders of effectiveness. As shown, 10 of the rules have first order effects only, 3 have second order effects only, 1 has third order effects only, and 1 has fourth order effects only. The remaining rules have multiple-order effects and required separate effectiveness assessments for each order affected by the rule.

Table 3-1
Rules and their Order Effects for Sources of Spills in this PRA

Rule (Docket Number)	First	Second	Third	Fourth
90-051		♦	♦	
90-052		♦		
90-068 DSC			♦	
90-068 SCC	♦	♦	♦	♦
90-071a		♦		
90-071		♦		
91-005	♦	♦	♦	
91-032	♦			
91-034 VRP		♦	♦	♦
91-034 E&P				♦
91-036		♦	♦	♦
91-045 L		♦	♦	
91-045 O	♦	♦	♦	
91-045 S		♦	♦	
91-046	♦			
91-202a	♦			
91-202	♦			
91-203	♦			
91-204	♦			
91-209	♦	♦		
91-211	♦	♦	♦	♦
91-212	♦	♦	♦	♦
91-216	♦			
91-218	♦			
91-222	♦			
91-223	♦	♦	♦	♦
91-225			♦	♦
91-228			♦	♦
91-235		♦	♦	♦
91-236		♦	♦	♦
92-007	♦			
93-081		♦	♦	
94-101	♦	♦	♦	♦

4. CORE GROUP RULES AND THEIR EFFECTS

Because not all OPA 90 rules have costs and benefits that are substantial or quantifiable, the total costs and benefits for the PRA can be adequately represented by a "core group" of 11 dominant rules. Table 4-1 lists the rules and clusters of rules selected for the core group. Descriptions of primary provisions for rules in the core group are found in Appendix B.

Table 4-1
OPA 90 Rules in the Core Group

OPA 90 Rule	PRA Rule	Short Title
90-051	I	Double Hulls
90-068 DSC	II	Deck Spill Control
90-068 SCC	III	Spill Source Control and Containment
91-045 L	IV	Lightering of Single Hull Vessels
90-071a	V	Overfill Devices
91-045 O	VI	Operational Measures for Single Hull Vessels
	VII	Licenses, Certificates, and Mariners' Documents
91-211		5-Year Certificate of Registry and Mariners' Documents
91-212		Driver Registration and Criminal Record Review
91-223		Drug Tests for Licenses, Certificates, and Mariners' Documents
94-101		Alcohol/Drug Abuse Suspension/Revocation of Licenses, Certificates, Mariners' Documents
91-005	VIII	Financial Responsibility
91-034 VRP	IX	Vessel Response Plans
91-036	X	Facility Response Plans
91-034 E&P	XI	PWS Equipment & Personnel Requirements

Individual rules, as defined by Coast Guard docket number, were subdivided or aggregated to facilitate estimating their respective benefits. A rule was subdivided if it addressed more than one measure of prevention in the chain of events leading to a spill or in responding to a spill (e.g., 90-068). Four rules addressing the qualifications and performance of mariners (91-211, 91-212, 91-223, 94-101) were aggregated into a single cluster for the PRA, reflecting their similarity and connectivity and the small individual contributions of three of the rules.

The impacts of the 11 core group rules on the four spill sources (tankers underway, barges underway, lightering operations, facilities) are presented in Table 4-2.

Table 4-2
Summary of OPA 90 Rules and their Impacts on Oil Spill Sources

PRA Rule Number	OPA 90 Rule CGD Number	Tankers		Barges		Lightering Operations	Facilities and Docks
		Double Hull	Single Hull	Double Hull	Single Hull		
I	90-051		♦		♦		
II	90-068 DSC					♦	♦
III	90-068 SCC	♦	♦	♦	♦	♦	♦
IV	91-045 L		♦		♦		
V	90-071a					♦	♦
VI	91-045 O		♦		♦		
VII	91-211	♦	♦	♦	♦	♦	♦
	91-212	♦	♦	♦	♦	♦	♦
	91-223	♦	♦	♦	♦	♦	♦
	94-101	♦	♦	♦	♦	♦	♦
VIII	91-005	♦	♦	♦	♦	♦	♦
IX	91-034 VRP	♦	♦	♦	♦	♦	
X	91-036						♦
XI	91-034 E&P	♦	♦				

The summary of core group rules and their orders of effectiveness are presented in Table 4-3. Expert Panel B (Appendix C) developed effectiveness factors—specific percentage-reductions from the baseline of oil spillage—for each rule and order of effectiveness. These specific percentage-reductions will be presented in more detail in Chapter 7.

Table 4-3
Core Group Rules and Orders of Effectiveness by Oil Spill Source

PRA Rule	Short Title	Reduced Adverse Effects	Tankers	Barges	Lightering Operations	Facilities and Docks
I	Double Hulls	Number of oil spills	♦	♦		
		Quantity of spilled oil	♦	♦		
II	Deck Spill Control	Quantity of spilled oil			♦	♦
III	Spill Source Control and Containment	Number of vessel casualties	♦	♦		
		Number of oil spills	♦	♦	♦	♦
		Quantity of spilled oil	♦	♦	♦	♦
		Quantity of spilled oil remaining	♦	♦	♦	♦
IV	Lightering of Single Hull Vessels	Number of oil spills	♦	♦		
		Quantity of spilled oil	♦	♦		
V	Overfill Devices	Number of oil spills			♦	♦
VI	Operational Measures for Single Hull Vessels	Number of vessel casualties	♦	♦		
		Number of oil spills	♦	♦		
		Quantity of spilled oil	♦	♦		
VII	Licenses, Certificates, and Mariners' Documents	Number of vessel casualties	♦	♦	♦	♦
		Number of oil spills	♦	♦	♦	♦
		Quantity of spilled oil	♦	♦	♦	♦
VIII	Financial Responsibility	Number of vessel casualties	♦	♦	♦	♦
		Number of oil spills	♦	♦	♦	♦
		Quantity of spilled oil	♦	♦	♦	♦
IX	Vessel Response Plans	Number of oil spills	♦	♦	♦	
		Quantity of spilled oil	♦	♦	♦	
		Quantity of spilled oil remaining	♦	♦	♦	
X	Facility Response Plans	Number of oil spills				♦
		Quantity of spilled oil				♦
		Quantity of spilled oil remaining				♦
XI	PWS E&P Requirements	Quantity of spilled oil remaining	♦			

5. OPA 90 PRAAM

In conjunction with this project, the Volpe team developed a computer software model—the OPA 90 Programmatic Regulatory Assessment Accounting Model (PRAAM). This model was required to handle the many data elements described in the next several sections, to accurately perform complex mathematical computations, to calculate the results of the reference case, and to provide a method to explore alternative analyses that changed the parameters of the reference case. PRAAM was flexible enough to accept data representing addition rules as long as the rules had universal application to total national traffic. PRAAM was used to store baseline oil spill conditions and to estimate overlapping effects of the OPA 90 core group of rules, national costs of these rules, and cost effectiveness of these rules.

PRAAM has the following features.

- Stores oil transport and oil spill history data
- Calculates alternative oil spill rates for forecasting alternative baselines
- Accepts alternative oil transport growth rates
- Projects alternative oil spill baselines
- Accepts alternative effectiveness factors for individual rules and events
- Calculates benefits of the core group of rules, without double counting
- Calculates marginal benefits of each rule
- Accepts initial capital expenditures and recurring yearly costs for individual rules
- Computes cost effectiveness of the core group of rules
- Computes marginal cost effectiveness of individual rules
- Accepts any subset of these 11 core group rules

Overview of Model Application and Inputs

PRAAM may be run once with all core group rules to calculate overall cost effectiveness. PRAAM may be run several times sequentially, omitting individual rules, to calculate marginal cost effectiveness by estimating the difference between the overall values run with and without each rule. PRAAM may also be run with a single rule to calculate its cost effectiveness. PRAAM presents the user with details of the reference case and all related parameter values. The user may change any of the input parameters to determine how sensitive the results are to each one.

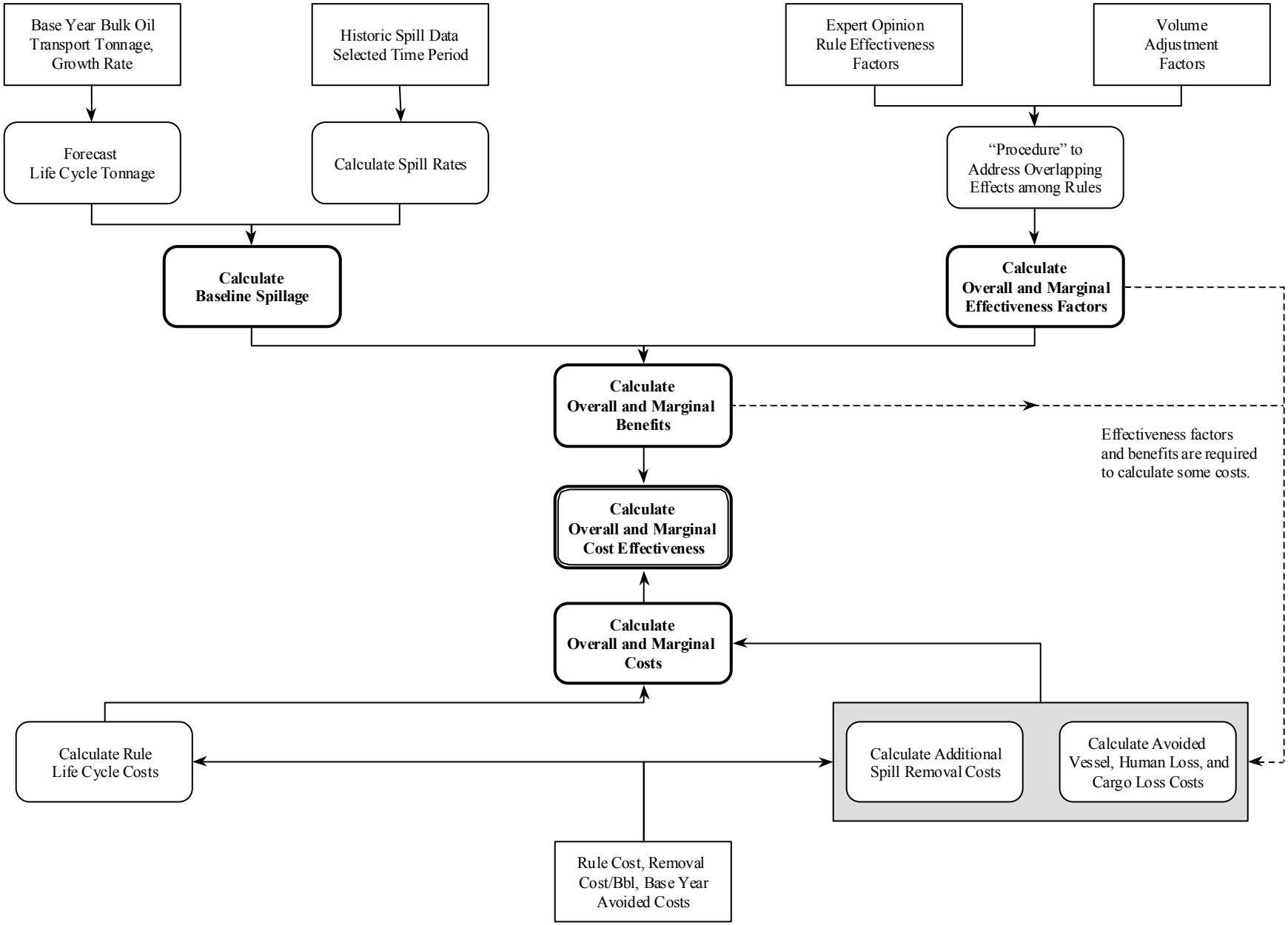
PRAAM Calculations

The flow and logic of PRAAM is presented in Figure 5-1. Baseline spills for the assessment period are combined with the effectiveness factors determined for each rule to estimate the benefits of the core group of OPA 90 rules. The costs of individual rules, as reported in RAs, are combined with cost savings to estimate the total costs of the core group. Finally, benefits are compared to total costs to estimate the cost effectiveness of the core group of OPA 90 rules. The effectiveness factors used to estimate benefits are also used to estimate spill removal costs and avoided costs, as indicated by the dotted lines in the figure.

User Options—Alternative Scenarios and Sensitivity Analysis Capabilities

Users can run alternative cases to test the sensitivity of individual rules' cost effectiveness during the assessment period to a range of uncertainties about input estimates of cost or effectiveness. Chapter 9 presents 10 alternative cases that vary input parameters from the reference case.

Figure 5-1
OPA 90 PRAAM Flow and Logic



BASELINE CONDITIONS

6. OIL TRANSPORT QUANTITIES AND OIL SPILL BASELINES

The benefits of the core group of OPA 90 rules are measured as BNSR—the barrels of oil not spilled or spilled and removed from the water before damage to the environment occurs. The benefit of individual rules (presented in Chapter 7) is the product of—

1) The effectiveness of each rule in reducing oil spills

2) Baseline oil spills (future oil spills in the absence of OPA 90)

Baseline oil spills for each year in the 30-year assessment period (1996–2025) are estimated as follows.

- Record the history of national total bulk oil transport quantities subject to OPA 90
- Forecast future quantities by applying average annual rates of growth
- Separate oil quantities transported by tank ship and tank barge
- Separate oil quantities transported by double hulls and nondouble hulls for rules that apply to either, but not both
- Separate oil quantities transported in Prince William Sound (PWS), Alaska for rules that apply only to PWS traffic
- Estimate average spill rates (quantity spilled per quantity transported) from available data from suitable historic periods
- Forecast oil spill baseline for each of four spill sources (tankers underway, barges underway, lightering operations, facilities) as the product of spill rates and projected oil transport quantities

The data presented in the figures in this section are documented in Appendix D.

Expert Panel A

A panel of 5 private-sector and Coast Guard experts—Expert Panel A—was asked to develop a forecast of baseline oil spillage in the absence of OPA 90. The Volpe team prepared oil spill forecasts, and the expert panel convened to review, critique, and modify those forecasts. Greater detail on Expert Panel A is found in Appendix C. The information in this chapter represents the

combined effort of the Volpe team, Expert Panel A, and the Coast Guard's Standards Evaluation and Analysis Division (G-MSR-1) staff.

Oil Transport Quantities, History (1975–1995) and Forecast (1996–2025)

The U.S. Army Corps of Engineers (ACOE) *Waterborne Commerce of the United States (WCUS) Part 5 National Summaries* is the basic source of historical yearly quantities of crude oil and petroleum products transported by tanker and barge in U.S. navigable waters[8] and the Exclusive Economic Zone[9] (EEZ).

Two ACOE commodities, petroleum coke and liquid natural gas, were deleted from the analysis to accurately represent the bulk oil transport affected by OPA 90. These commodities comprised 6.7 percent of the total petroleum tons for 1993 to 1995, and this percentage was subtracted from the yearly petroleum tons transported from 1973 to 1995. Figure 6-1 presents the distribution of oil transport tons affected by OPA 90 by commodity and method of transport, based on 1993 ACOE data. As shown, most of the petroleum transported in U.S. waters is crude oil.

[8] 33 CFR 2.05-25

[9] 33 CFR 2.05-35

Figure 6-1
Petroleum Commodities (Millions of Tons) Transported in U.S. Waters in 1993 by Tankers and Barges

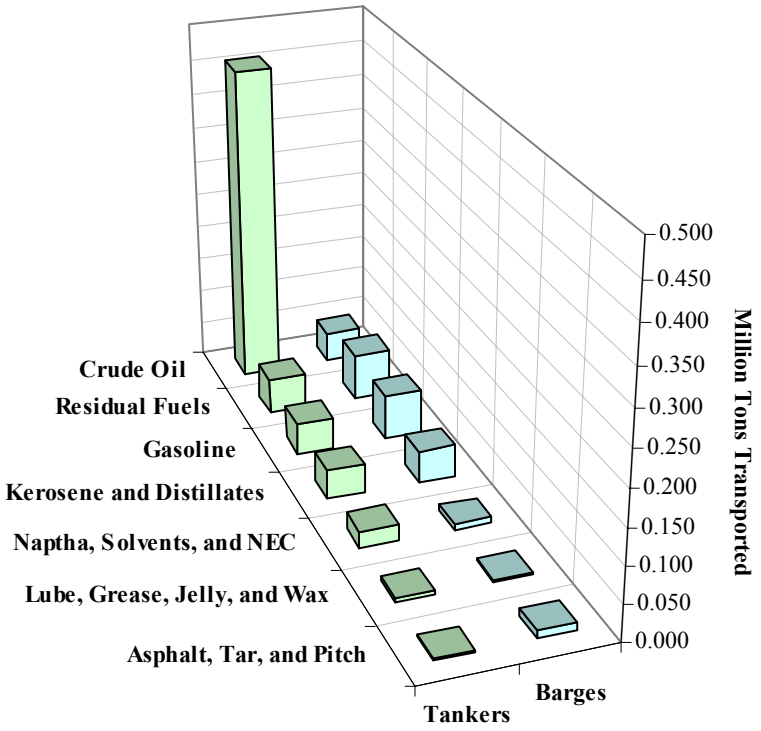
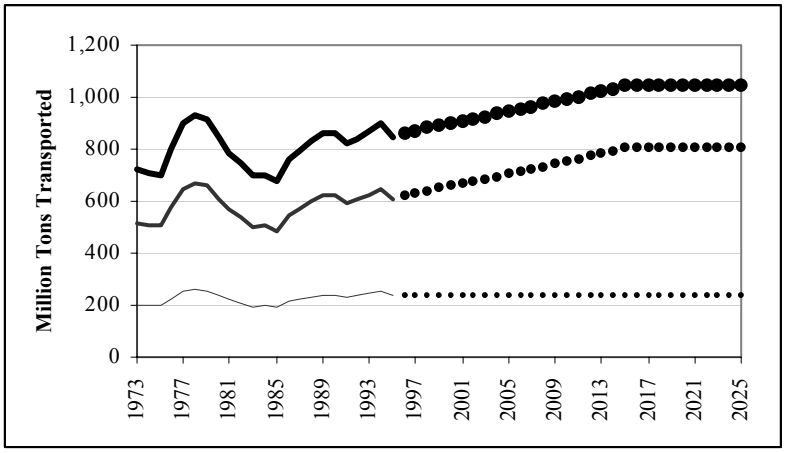


Figure 6-2 presents the historical tons of oil transported by tankers and barges for 1973 to 1995 (ACOE data). It also presents projected oil transport, with a 1-percent annual growth rate through 2015 and no growth 2016 to 2025.

Figure 6-2
Oil Transport in U.S. Waters, Historical Transport (1973–1995, ACOE data) and Forecasted Transport (1 Percent Annual Growth Rate)



In order to forecast oil quantities transported 1996 to 2025, average annual growth rates were applied to the 1996 value.[10] The primary analysis in this PRA—the reference case—uses a 1 percent annual growth rate for the 30-year assessment period, as supported by U.S. Department of Energy (DOE) Information Administration's *Annual Energy Outlook 1997*. In a sensitivity analysis, an alternative annual growth rate of 3 percent is projected (see Chapter 9, Alternative Case 1). Expert Panel A was uncertain with forecasting beyond 2015 and recommended that the reference case growth be truncated at 2015 (i.e., no growth beyond 2015). In the sensitivity analysis using the 3 percent growth rate, this growth is assumed to continue throughout the 30-year assessment period.

Total tons of bulk oil transported in 1993, 1994, and 1995 were distributed approximately 72 percent and 28 percent between tankers and barges, respectively. This distribution was assumed for 1973 to 1995 for the purposes of estimating average spill rates. Expert Panel A recommended that all future growth in U.S. oil transport be assigned to tankers only, holding constant the annual transport quantity for barges between 1996 and 2025. The expert panel noted that barge transport has been dominated by domestic movement of petroleum products and believed that the future increases in petroleum-product consumption would be supplied by offshore refineries and transported in U.S. waters by tankers rather than barges.

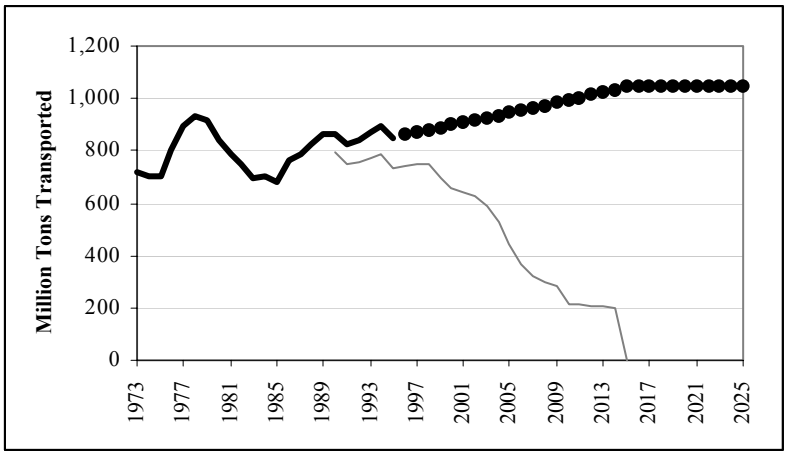
Nondouble Hull Phase Out

OPA 90 requires that nondouble hull vessels transporting bulk petroleum be phased out by 2015 in favor of double hulls. In the interim, nondouble-hull vessels are subject to specific regulations, affecting only the portion of total petroleum shipments transported in nondouble hull vessels. Expert Panel A estimated the effects of the single hull phase out schedule and the increased use of oil tankers. The expert opinion is consistent with similar information contained in a National Research Council (NRC) Marine Board study.[11] Figure 6-3 compares the phase out of nondouble hull vessels with the total oil transport forecast for the reference case.

[10] ACOE data recorded a substantial drop in bulk oil tonnage in 1995; therefore, the average of 1991–1995 was used for 1996, and the average annual growth rate was applied to each year after 1996 using this refined value.

[11] *Effects of Double-Hull Requirements on Oil Spill Prevention*: *Interim Report*, Committee on Oil Pollution Act of 1990 (Section 4115) Implementation Review, Marine Board, Commission on Engineering and Technical Systems of the National Research Council. 1996.

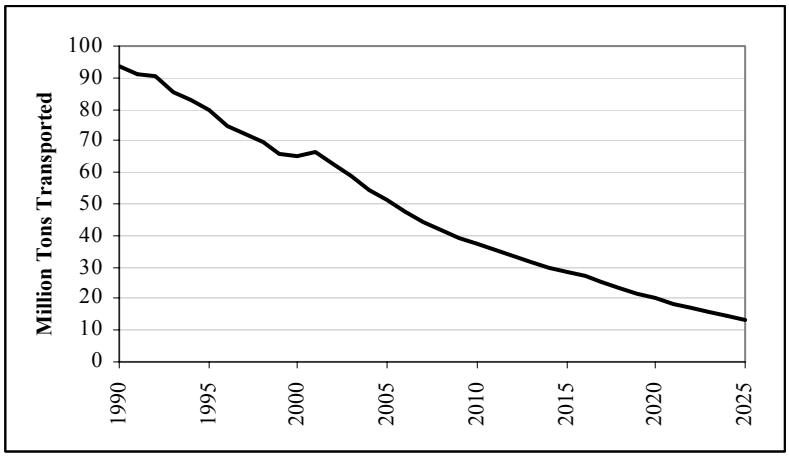
Figure 6-3
Phase Out of Nondouble Hull Vessels for the Reference Case



Prince William Sound Tanker Traffic Forecast

One OPA 90 regulation affects oil tankers serving Valdez, Alaska, via Prince William Sound (PWS). The State of Alaska's forecast of statewide oil production was used to develop a trendline that was then applied to the 1995 oil quantity reported in ACOE's *Waterborne Commerce* statistics for ports within PWS. The State of Alaska predicts that oil production will slow in the future; thus, oil transported in PWS will decrease, as shown in Figure 6-4. The 1990–2020 projection is based on the fall 1996 Reference Case Forecast, Revenue Source Book (State of Alaska Department of Revenue). The projection 2020–2025 is an extrapolation of the negative growth rate of traffic.

Figure 6-4
Oil Transport Trend for Prince William Sound, Alaska



Oil Spill History

The Coast Guard's Oil and Hazardous Substance Spill Database contains the history of oil spills in U.S. navigable waters and the EEZ. The yearly numbers of spills and total gallons spilled from 1973 to 1995 were extracted from this database. Yearly spill events were aggregated into the four major sources of spills (see Chapter 2), as presented in Figure 6-5. Spills that occurred as the result of an event while the vessel was underway (e.g., groundings or collisions) were allocated to tankers and barges underway. Spills that originated on tankers or barges while lightering were allocated to lightering operations, while spills that occurred on tankers and barges while tied to docks or piers (or other loading facilities) were allocated to facilities.

Figure 6-5
Oil Spill Sources

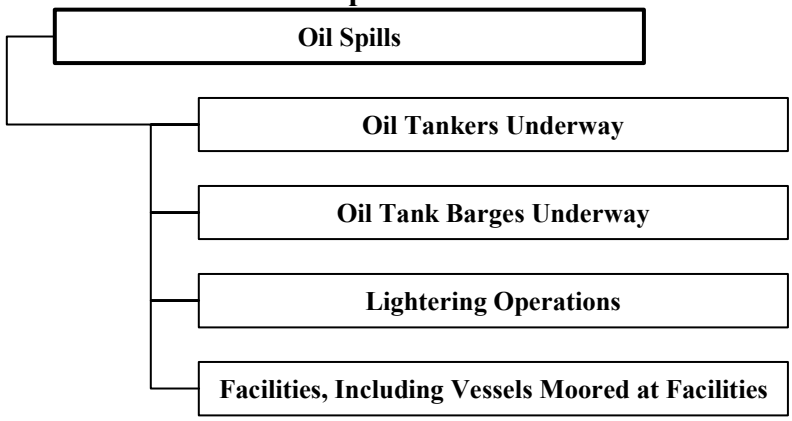
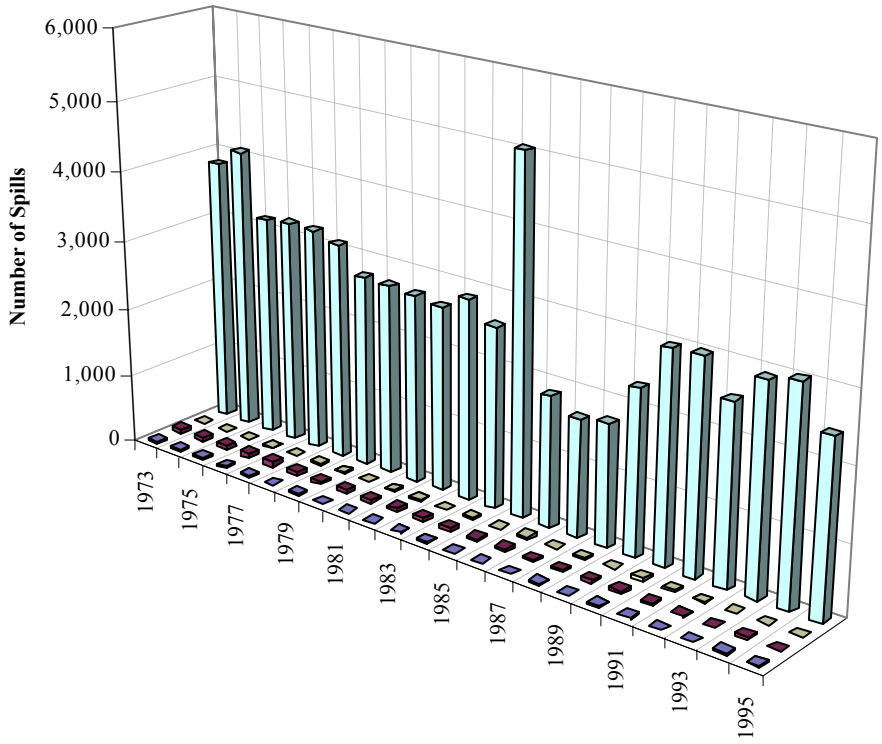


Figure 6-6 presents the total number of spills allocated yearly to each spill source from 1973 to 1995. As shown, a large number of spills for vessels at facilities dominate the total number of spills for the time period. By contrast, Figure 6-7 presents the total gallons of oil spilled during the same time period. While most spills take place at facilities, most gallons of oil spilled come from tankers underway.

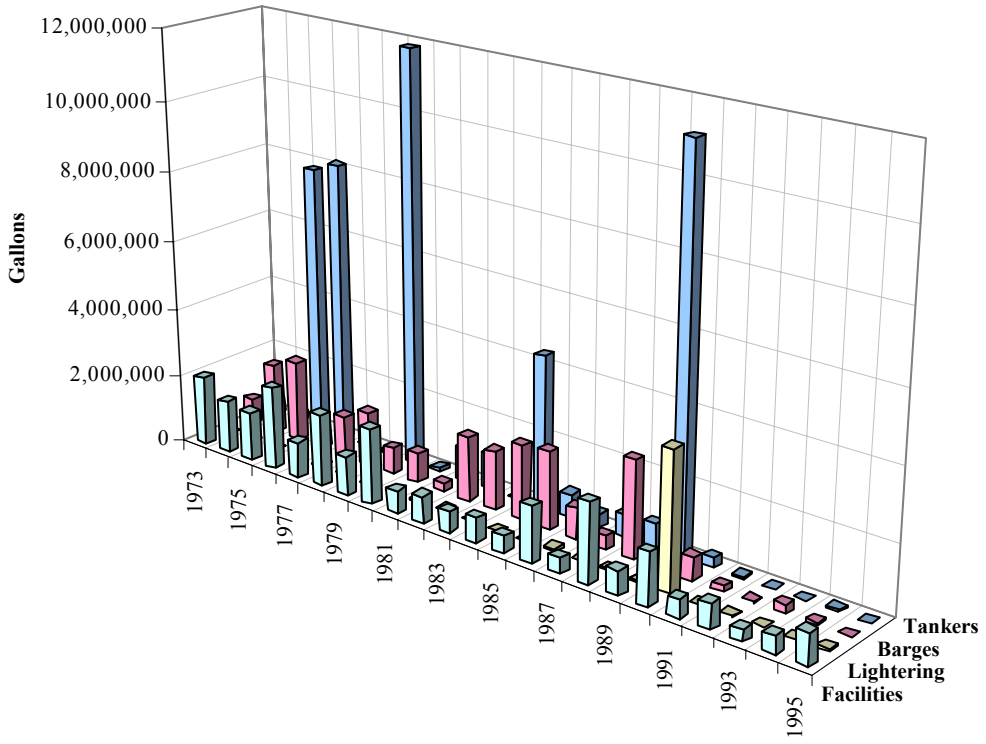
Figure 6-6
Number of Oil Spills in U.S. Waters by Spill Source, 1973–1995



These data were the bases for estimating average spill rates to project future oil spill baselines. Average spill rates were calculated by dividing the total gallons spilled for each spill source over the time period by the corresponding tons of oil transported over the time period. The Volpe team examined three time periods: 1973–1990, 1973–1980, and 1981–1990. The spill data for 1991–1995 were considered incomplete at the time of the PRA analysis. The extent to which OPA 90 had already influenced oil spills during this time period was also unclear. Expert Panel A and the Volpe team concurred that 1981–1990 was the most suitable time period for calculating average spill rates for the reference case oil spill baseline. Several expert panel members, however, believed that these data may underestimate slightly the actual quantity of spilled oil. Their work

on a Marine Board project suggested that the Coast Guard pollution database might have understated the total spillage by 10 to 15 percent.[12]

Figure 6-7
Gallons of Oil Spilled in U.S. Waters by Spill Source, 1973–1995



Certain OPA 90 regulations address oil spills on decks and spills resulting from overfilling cargo or bunker fuel tanks. Deck spills from lightering operations and overfill spills from facilities were estimated as fixed percentages of the spillage from each of these respective sources. The percentage used for deck spills is 0.37 percent and for overfill spills is 4.6 percent.[13]

[12] *Ibid*.

[13] Derived from data in *Discharge Removal Equipment Regulatory Evaluation*. CGD 91-068, prepared by the Volpe Center for the Coast Guard, May 1993; and *U.S. Coast Guard Evaluation for Regulations Requiring the Installation of Overfill Devices*. CGD 90-071a, November 2, 1993, respectively.

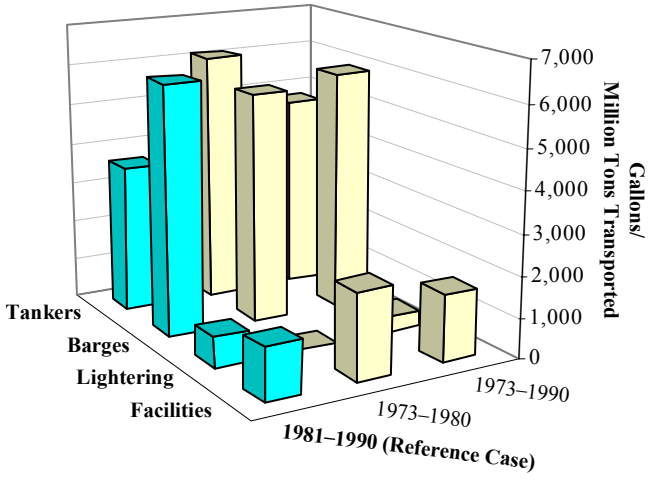
Oil Spill Removal

Several OPA 90 regulations address capabilities to contain and remove oil spilled in the water before it does substantive damage to the marine environment—it is removed from the water within 72 hours of spilling. Some OPA 90 rules reduce total oil spilled, a few increase the quantity of spilled oil removed, and a few do both. The OPA 90 total benefit is the reduced quantity of spilled oil remaining in the water, calculated as the difference between the baseline case and the OPA 90 case. Based on the recommendation of Expert Panel A, the national average pre-OPA 90 spill removal (within 72 hours) was assumed to be 10 percent, in the absence of any definitive data on oil spill removal.

Oil Spill Baselines, 1996–2025

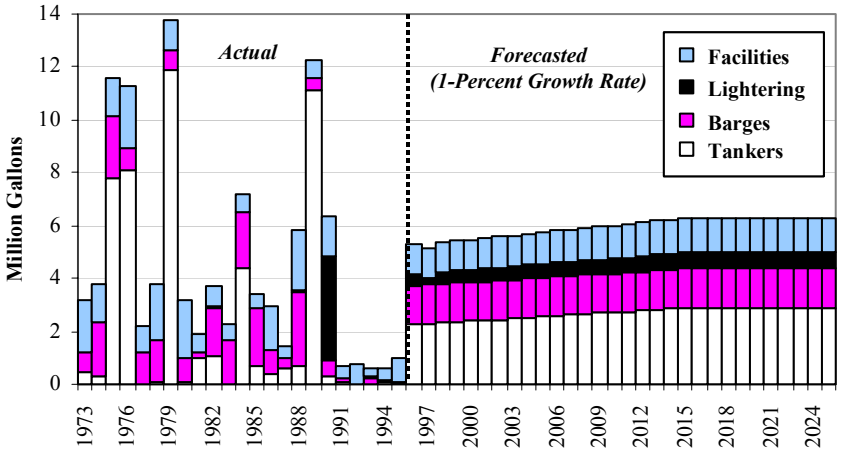
The oil spill baseline for the reference case is based on a 1-percent annual transport growth and average oil spill rates derived from 1981–1990 spill data. The reference case accounts for the nondouble hull phase out, the PWS tanker traffic forecast, and deck and overfill spills. The average quantity of oil spilled per transport quantity for the reference-case time period and the two other time periods for each of the four spill sources is presented in Figure 6-8.

Figure 6-8
Oil Spill Rates (Gallons per Million Tons Transported) in U.S. Waters for the Reference Case and Two Other Time Periods by Spill Source



Average spill rates (gallons per million tons of oil transported), 1981–1990, were multiplied by the forecasted oil transport (millions of tons) to estimate future oil spills over the 30-year assessment period, 1996–2025. Figure 6-9 presents the spill history from each spill source and the forecasted baseline. While the historical data highlight the apparent randomness of oil spills, the forecasted spillage is smoothed over time because it is based on average spillage.

Figure 6-9
OPA 90 Baseline Oil Spills for the Reference Case, Historic Data and Forecasted Spills



BENEFIT, COST, AND COST EFFECTIVENESS OF OPA 90

7. BENEFIT OF OPA 90

Developing a consistent estimate of the potential effectiveness of 11 core group rules in OPA 90 was challenging. The project team assembled a group of experts, Expert Panel B, to ascertain the percent change from the baseline that could be reasonably attributed to each rule in the core group (detail on Expert Panel B can be found in Appendix C).

Figure 7-1 presents a conceptual representation of the objectives of OPA 90. The pie graph on the left represents the 30-year assessment period oil quantity that would be spilled in the absence of OPA 90. The pie graph on the right represents the oil quantity that would be spilled even with OPA 90. The large, gray portions are the quantity of spilled oil remaining in the water following an oil spill. The small, white portions of the graphs represent the quantity of spilled oil that would be removed from the water. The difference between the two pie graphs is the amount of oil that would be prevented from being spilled as a result of OPA 90. With OPA 90 rules, the total oil spilled is less than without OPA 90 and the relative amount removed from the water in the event of a spill is greater. The overall effectiveness of OPA 90 is represented by the percentage reduction in the large segment of the left pie graph.

Figure 7-1
Conceptual Representation of the Effectiveness of OPA 90

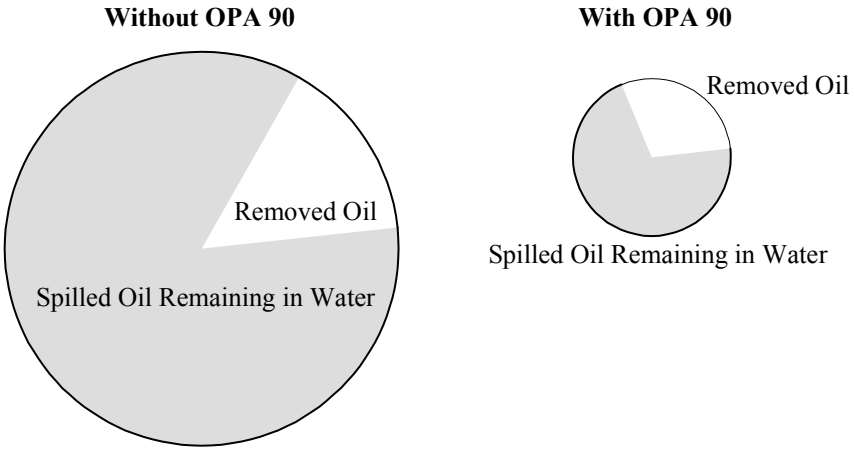


Figure 7-2 presents a spill event tree (see Chapter 3) of the four orders of events that each rule may address (see Chapter 4). OPA 90 rules are intended to prevent vessel casualties or equipment failures (first-order events), prevent spills in the event of a casualty or failure (second-order events), reduce the quantity of oil spilled in the event of a spill (third-order events), or reduce the amount of oil remaining in the water after a spill (fourth-order events).

Figure 7-2
Oil Spill Event Tree and Orders of Events

Expert Panel B

A panel of 7 private-sector and Coast Guard experts—Expert Panel B—was asked to assess the effects of each rule on the four major events (casualties/failures, spills, quantity spilled, quantity removed) in the event tree and to estimate a percent change for each individual rule. Panel members estimated effectiveness ranging from negative values to 95 percent (negative values reflected the panel's opinion that an individual rule could actually be counterproductive in certain events—e.g., double hulls in certain types of accidents). Greater detail on Expert Panel B is found in Appendix C.

The panel represented a broad base of experience related to the waterborne oil transport system, its ability, and industry motivations to respond to regulations. Panel members were encouraged to exchange information and opinions, to discuss the issues raised by the questions posited, to form individual opinions about each rule's effectiveness, and to document individual estimates. The estimates of effectiveness presented in this PRA represent the average of the panel as a whole, as interpreted and aggregated by the Volpe team, not the findings of any particular individual.

Matrix of Individual OPA 90 Rule Effectiveness Factors

Table 7-1 presents the reduced adverse effects the core group of rules was expected to have on the four orders of spill events (casualties/failures, spills, quantity spilled, quantity removed).

Table 7-1
OPA 90 Rules and Reduced Adverse Effects

PRA Rule	Short Title	Reduced Adverse Effects
I	Double Hulls	Number of oil spills Quantity of spilled oil
II	Deck Spill Control	Quantity of spilled oil
III	Spill Source Control and Containment	Number of vessel casualties Number of oil spills Quantity of spilled oil Quantity of spilled oil remaining in water
IV	Lightering of Single Hull Vessels	Number of oil spills Quantity of spilled oil
V	Overfill Devices	Number of oil spills
VI	Operational Measures for Single Hull Vessels	Number of vessel casualties Number of oil spills Quantity of spilled oil
VII	Licenses, Certificates, and Mariners' Documents	Number of vessel casualties Number of oil spills Quantity of spilled oil
VIII	Financial Responsibility	Number of vessel casualties Number of oil spills Quantity of spilled oil
IX	Vessel Response Plans	Number of oil spills Quantity of spilled oil Quantity of spilled oil remaining in water
X	Facility Response Plans	Number of oil spills Quantity of spilled oil Quantity of spilled oil remaining in water
XI	PWS Equipment & Personnel Requirements	Quantity of spilled oil remaining in water

Because the effectiveness factors for Rule I (Double Hulls) were complex to develop, Expert Panel B disaggregated vessel casualties and equipment failures, into more specific casualty types. Table 7-2 presents the distribution of the types of casualties, which were used to weight the estimates from the expert panel. Table 7-3 presents the effectiveness estimates for double hulls for each casualty type. Each effectiveness estimate is the arithmetic mean of seven individual estimates from the expert panel.

Table 7-2
Double Hull Vessel Casualties Distributions of Spills and Quantity Spilled for Tankers and Barges

Type of Casualty	Percent Oil Spills	Percent of Quantity of Spilled Oil
Low energy grounding	2.75	8.26
High energy grounding	0.69	33.02
Low energy collision	3.47	12.45
High energy collision	0.38	12.45
Explosions/fire	0.27	13.20
Structural failure	21.87	7.03
Operational	70.57	13.59
Total	100.00	100.00

Table 7-3
Double Hull Rule Effectiveness (Percent Reduction from the Baseline), by Spill Events and Spill Sources

Vessel Casualty Type	Spill Event Targeted	Effectiveness (Percent Reduction)	
		Tankers Underway	Barges Underway
Low energy grounding	Number of oil spills	84	91
	Quantity of spilled oil	52	61
High energy grounding	Number of oil spills	21	26
	Quantity of spilled oil	33	33
Low energy collision	Number of oil spills	79	89
	Quantity of spilled oil	-2	0
High energy collision	Number of oil spills	20	24
	Quantity of spilled oil	-2	0
Explosions/fire	Number of oil spills	0	0
	Quantity of spilled oil	9	9
Structural failure	Number of oil spills	37	47
	Quantity of spilled oil	56	57
Operational	Number of oil spills	0	0
	Quantity of spilled oil	5	4
Weighted average, number of spills		**13**	**16**
Weighted average, quantity of spilled oil		**21**	**22**

Table 7-4 presents the effectiveness factors for all rules in the core group. As shown, effectiveness estimates for Rules II (Deck Spill Control) and V (Overfill Devices) are relatively high, though they apply to small baseline spill quantities—0.37 percent and 4.6 percent, respectively. Effectiveness estimates for Rule VI (Operational Measures for Single Hull Vessels) are composites of eight measures. Expert Panel B assigned separate effectiveness estimates to each measure that were then summed to estimate the effectiveness of Rule VI as a whole. While the project team initially determined that some rules would have effects on oil spills (see Table 4-3), the expert panel estimated the rule would have negligible impacts and the effectiveness factors would be zero (for example, Rule III—Spill Source Control and Containment).

Table 7-4
Core Group Rules and Their Effectiveness (Percent Reduction from the Baseline) on Oil Spill Sources

PRA Rule	Short Title	Reduced Adverse Effects	Tankers	Barges	Lightering Operations	Facilities and Docks
I	Double Hulls	Number of oil spills	Table 7-3	Table 7-3		
		Quantity of spilled oil	Table 7-3	Table 7-3		
II	Deck Spill Control	Quantity of spilled oil			72	72
III	Spill Source Control and Containment	Number of vessel casualties	1	3		
		Number of oil spills	2	2	0	0
		Quantity of spilled oil	4	6	4	2
		Quantity of spilled oil remaining	2	2	3	3
IV	Lightering of Single Hull Vessels	Number of oil spills	0	0		
		Quantity of spilled oil	2	4		
V	Overfill Devices	Number of oil spills			84	86
VI	Operational Measures for Single Hull Vessels	Number of vessel casualties	12	9		
		Number of oil spills	0	1		
		Quantity of spilled oil	0	1		
VII	Licenses, Certificates, and Mariners' Documents	Number of vessel casualties	1	3	0	0
		Number of oil spills	0	0	0	0
		Quantity of spilled oil	1	1	1	1
VIII	Financial Responsibility	Number of vessel casualties	35	33	35	34
		Number of oil spills	6	6	9	9
		Quantity of spilled oil	9	10	22	22
IX	Vessel Response Plans	Number of oil spills	1	1	7	
		Quantity of spilled oil	1	1	2	
		Quantity of spilled oil remaining	6	6	17	
X	Facility Response Plans	Number of oil spills				16
		Quantity of spilled oil				11
		Quantity of spilled oil remaining				17
XI	PWS E&P Requirements	Quantity of spilled oil remaining	15			

Comparison of Expert Panel B and RA Effectiveness Factors

Most RAs for the 11 core group rules quantified benefits, though 3 RAs only gave information to derive effectiveness estimates that corresponded to reported benefits. Table 7-5 presents the estimates derived from the RAs to the estimates derived from Expert Panel B. Expert Panel B's estimate is slightly lower for Rule IX (Vessel Response Plans) but notably lower for Rules I and XI (PWS Equipment and Personnel Requirements).

Table 7-5
Comparison of RA and Expert Panel B Estimates of Rule Effectiveness
(Percent Reduction from the Baseline)

Derived Overall Effectiveness	Rule I: Double Hulls	Rule IX: Vessel Response Plans	Rule XI: PWS Equipment & Personnel Requirements
RA	54.0[a]	15.5[b]	22.0[c]
Expert Panel B	32.0[d]	14.8[e]	15.0

[a] U.S. Coast Guard. *Interim Regulatory Impact Assessment for the Oil Pollution Act of 1990, Titles IV and V*. October 28, 1991, page 71, Table 3.4.4.

[b] U.S. Coast Guard. *Interim Regulatory Impact Assessment for Vessel Response Plans*. March 1993. The overall effectiveness estimate of 0.155 is a 26-year average.

[c] U.S. Coast Guard. *Interim Final Regulatory Evaluation for the Oil Pollution Act of 1990, Section 5005 Equipment and Personnel Requirements under Vessel Response Plans for Tank Vessels Operating in Prince William Sound*. January 1993. The overall effectiveness estimate of 0.220 is a 10-year average.

[d] The overall first order and second order effectiveness estimates are based on weighted averages of the panel's effectiveness estimates for each vessel casualty type and are estimated separately for tankers and barges. The weights used in the overall first order average are the frequencies of each vessel casualty type by the number of spill occurrences. The weights used in the overall second order average are the frequencies of each vessel casualty type by the volume of spill occurrences. First and second order effectiveness estimates were combined to eliminate double counting. The 0.320 estimate is the weighted average for tankers and barges, using weights of 0.72 and 0.28, respectively.

[e] Weighted average of overall effectiveness for tankers, barges, and lightering operations using weights of 0.72/1.72, 0.28/1.72, and 0.72/1.72, respectively.

Application of Effectiveness Factors to Oil Spill Baselines

In this PRA, the benefits of OPA 90 are BNSR—the barrels of oil not spilled into the water plus the barrels of oil spilled and removed from the water before substantive damage to the marine environment occurs. Benefits are the product of the projected oil spill baseline, in the absence of OPA 90, and the effectiveness factors attributed to individual OPA 90 rules, accounting for the overlapping effects of the rules to avoid double counting. Benefits are expressed in BNSR, rather than in monetary terms. Benefits do not include avoided costs of spill response, containment, or removal, but do include avoided costs of vessel damage, time lost for repairs, lost cargo, human injuries, and fatalities. The avoided costs that are included can be expressed in monetary terms and are subtracted from the cost estimates presented in Chapter 8. These avoided costs are estimated using the same procedure as for nonmonetized benefits.

Reference Case Assessment Period Benefit

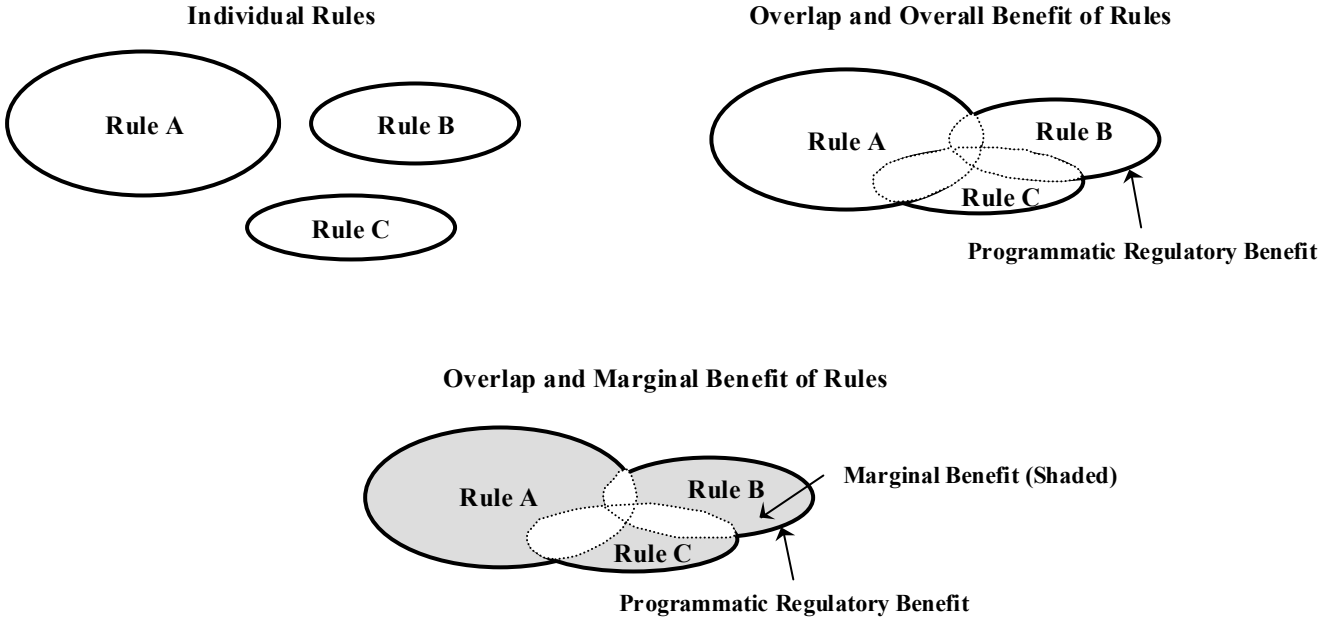
The total benefits over the 30-year assessment period are a function of several parameters, each with degrees of variance and uncertainty. The reference case for this PRA combines the analysis and expertise of the Volpe team, the expert panels, and the Coast Guard. The parameters in the reference case are varied in a series of sensitivity analyses presented in Chapter 9. The reference case parameters are as follows.

- Assessment period: 1996–2025
- Assessment period discount rate: 7 percent
- Bulk oil transport growth rate: 1 percent per year, 1996–2015
- Future oil spill rate derived from past years: 1981–1990
- Pre-OPA 90 oil spill removal rate: 10 percent

Overall Benefit—Overlap and Interaction

The methodology for accounting for the overlapping effects of the core group of rules is quite elaborate and is presented in Appendix E. Figure 7-3 presents a simplified conceptualization of OPA 90 benefits. In the first group (upper left), individual rules are considered in isolation from one another. There are no overlapping benefits. Once the rules are considered together (upper right), the benefits overlap, and the overall benefit—or programmatic regulatory benefit—is the area within the dark outline, without the overlapping areas. The marginal benefit (lower middle) of a particular rule is the incremental amount of the overall benefit that is contributed by only that rule. It is the shaded area within the dark outline and outside the nonshaded areas.

Figure 7-3
Conceptual Representation of Benefits from OPA 90



OPA 90 Core Group Assessment Period Benefit

Table 7-6 presents the benefit for the reference case. Total baseline spillage over the 30-year assessment period was an estimated 1.8 million BNSR (1996 TPV). The estimated overall benefit of the core group of rules is 1.2 million BNSR. An estimated 67.1 percent of the baseline oil spillage, therefore, will be prevented with OPA 90 over the next 30 years. Rule VIII (Financial Responsibility) provides the greatest benefit while Rule II (Deck Spill Control) provides the least benefit.

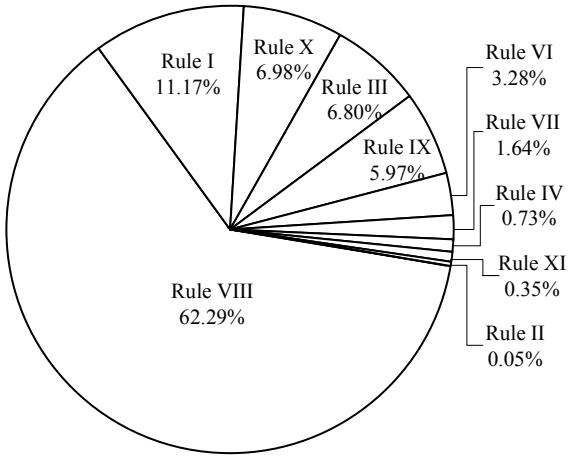
Table 7-6
OPA 90 Core Group Benefit (1996 TPV BNSR) for the Reference Case, in Order of Benefit

1996 Baseline Spillage TPV: 1,818,726 BNSR **1996 Overall Benefit TPV: 1,221,063 BNSR** **Overall Effectiveness of the Core Group: 67.1 Percent**			
PRA Rule	**Short Title**	**Marginal Benefit (BNSR)**	**Individual Benefit (BNSR)**
VIII	Financial Responsibility	525,316	851,302
I	Double Hulls	94,172	216,780
X	Facility Response Plans	58,838	138,896
III	Spill Source Control and Containment	57,320	154,581
IX	Vessel Response Plans	50,312	130,590
VI	Operational Measures for Single Hull Vessels	27,629	69,546
VII	Licenses, Certificates, and Mariners' Documents	13,863	40,008
V	Overfill Devices	6,287	21,383
IV	Lightering of Single Hull Vessels	6,144	16,596
XI	PWS Equipment & Personnel Requirements	2,989	8,094
II	Deck Spill Control	411	1,450

Table 7-6 also displays the marginal and individual benefit of each rule. The marginal benefit of any particular rule is always less than the individual benefit of that rule because the individual benefit considers the rule in isolation. In the marginal benefits analysis, that same rule is part of a larger group of rules, and the overlapping benefits have been subtracted. The benefits presented in Table 7-6 are consistent with the benefits reported in individual RAs for these rules.

The net contribution of each rule to the overall benefit cannot be isolated because of the overlapping nature of the rules. The net contribution of each rule can be approximated, however, using the marginal benefit as a weight. Figure 7-4 shows the distribution of the 1.2 million barrel overall benefit of the core group using marginal benefits to weight each rule.

Figure 7-4
Relative Contribution of Each Rule to Overall Benefit Using Marginal Benefit as a Weight



8. COST OF OPA 90

The costs of individual rules in the core group are the combination of industry compliance and government enforcement of these rules. Individual rule costs were estimated for each of the 30 years of the assessment period (1996–2025) in 1996 constant dollars. For each rule the stream of yearly costs over the assessment period was discounted to 1996 at a 7 percent discount rate. Discounted compliance and enforcement costs were then reduced by monetized benefits (i.e., cost savings from avoided costs) attributable to reducing accidents. These avoided costs are subtracted from the estimated costs rather than added to the estimated benefits because the benefits are expressed in terms of BNSR rather than in monetary terms. Avoided costs attributable to OPA 90 are associated with vessel damage, time lost for repairs, lost cargo, human injuries, and fatalities. These avoided costs are estimated using the same procedure as for nonmonetized benefits (Chapter 7). Avoided costs are also estimated for each year of the assessment period and are discounted to 1996 at a 7 percent discount rate before they are subtracted from the compliance and enforcement costs.

RA Assessment Period Costs for Compliance and Enforcement

The RAs for individual rules (Chapter 2) were the primary source for costs of compliance and enforcement. In a few cases, the Coast Guard made adjustments to published RA costs. In such cases, the Volpe team used the updated costs for this PRA. Details of the cost methodology for compliance and enforcement costs are in Appendix F.

The assessment time periods varied among RAs from a few years to as many as 23. To extrapolate rule costs consistently over the 30-year assessment period in the PRA, the Volpe team deconstructed each rule's compliance and enforcement costs reported in its RA into capital costs and annual costs. Capital costs include equipment and other major expenditures that occur only once or twice during the 30-year assessment period. Annual costs include annual operation and maintenance costs over the assessment period.

For all but two rules, capital equipment was assumed to have a life cycle of 15 years.[14] For this PRA, therefore, two complete sets of capital equipment were purchased in the 30-year assessment period; the first in 1996, the second in 2011. The 2011 capital purchase was

[14] For Rule I (Double Hulls), it was assumed that the life of double-hull vessels was the 30-year assessment period of the PRA. For Rule VII (Licenses, Certificates, and Mariners' Documents), one of the four constituent regulations required capital expenditures for computer hardware, software, and electronic interfacing with the National Driver Registry's database. A life cycle of only 5 years was assumed for these expenditures to reflect the accelerated rate of computer-system obsolescence and replacement. Six sets of hardware and software were assumed to be purchased during the 30-year assessment period.

discounted to 1996 to calculate the TPV of capital expenditures in the assessment period. The cost of capital equipment is assumed to be the same in 2011 as in 1996. Additionally, the costs for Rule VI (Operational Measures for Single Hull Vessels) are estimated only for the period 1996–2015. The costs are not extrapolated to 2025 because single hull vessels will be phased out by 2015.

Annual costs in some RAs varied each year, and some RAs reported only the TPV of the recurring costs over the RA assessment period. In such cases, an annualized equivalent cost that could be applied over the 30-year assessment period of the PRA was calculated. Also, some RAs used a 10 percent discount rate when calculating TPV. In these instances, the TPV was first converted to an annualized equivalent cost using a 10 percent discount rate, and then this annualized stream was discounted to a TPV using a 7 percent discount rate.

After converting RA reported costs to appropriate capital and annual costs, the Volpe team inflated costs to 1996 constant dollars. A unique inflation factor for each rule was developed using the ratio of the 1996 Gross National Product (GNP) price deflator to the GNP price deflator for the year of the RA.

Table 8-1 presents individual capital and annual costs estimated from each RA, appropriate inflation factors, and capital and annual costs in 1996 TPV. Table 8-2 presents the 1996 TPV of the compliance and enforcement costs for each of the 11 core group rules over the entire 30-year assessment period (1996–2025). In both of these tables, costs represent the reference case.

Table 8-1
Compliance and Enforcement Costs for Core Group Rules, RA Estimates and Adjusted PRA Estimates

PRA Rule	Short Title, RA Year	Adjusted RA TPV of Capital Costs	RA Constant Annual Costs	Inflation Factor for 1996*	TPV of All Capital Costs ($1996)	Annual Costs ($1996)
I	Double Hulls, 1991	$3,345,229,320	$80,856,133	1.1274	$3,771,411,535	$91,157,204
II	Deck Spill Control, 1993	1,274,296	806,360	1.0692	1,362,477	862,160
III	Spill Source Control and Containment, 1993	189,115,007	942,241	1.0692	202,201,765	1,050,212
IV	Lightering of Single Hull Vessels, 1994	7,211,341	0	1.0458	7,541,620	0
V	Overfill Devices, 1991	141,933,606	1,521,000	1.1274	160,015,947	1,714,775
VI	Operational Measures for Single Hull Vessels, 1996	33,647,654	11,386,058	1.0000	33,647,654	11,386,058
VII	Licenses, Certificates, and Mariners' Documents, 1993	60,529	5,639,456	1.0692	64,718	6,029,706
VIII	Financial Responsibility, 1994	0	360,500,000	1.0458	0	377,010,900
IX	Vessel Response Plans, 1992	346,068,774	196,780,831	1.0970	379,637,445	215,868,572
X	Facility Response Plans, 1992	24,507,679	10,244,731	1.0970	26,884,924	11,238,470
XI	PWS Equipment & Personnel Requirements, 1990	20,992,956	19,312,644	1.1708	24,578,553	22,611,244

* Ratio of GNP Price Deflators (1996/RA Year)
GNP Price Deflators (1992 = 100); Department of Commerce, Bureau of Economic Analysis, February 1997.
1990: 93.7
1991: 97.3
1992: 100
1993: 102.6
1994: 104.9
1995: 107.6
1996: 109.7
RA reported costs are used for the reference case for all except two rules. Updated costs are used for Rules I and VIII. RA costs for Rules I and VIII are used in Alternative Case 7 in the sensitivity analyses presented in Chapter 9.

Table 8-2
TPV ($1996) Compliance and Enforcement Costs for the Reference Case (1996–2025), in Order of Cost

PRA Rule	Short Title	Compliance and Enforcement Costs (1996–2025, $1996)
I	Double Hulls	$6,413,027,637
IX	Vessel Response Plans	3,245,869,985
VIII	Financial Responsibility	451,440,918
XI	PWS Equipment & Personnel Requirements	324,803,281
III	Spill Source Control and Containment	216,146,138
V	Overfill Devices	182,784,171
X	Facility Response Plans	176,105,666
VI	Operational Measures for Single Hull Vessels	159,567,059
VII	Licenses, Certificates, and Mariners' Documents	80,125,189
II	Deck Spill Control	12,809,956
IV	Lightering of Single Hull Vessels	7,541,620

Updated Costs for Selected Rules

Rule I (Double Hulls)

Updated costs for Rule I (Double Hulls) became available during the course of this study and were incorporated into the reference case. During the final session of the Expert Panel B workshop, several members indicated that the existing RA estimates of costs for industry compliance were outdated. The panel suggested using more recent industry cost data, particularly in light of the then concurrent NRC Marine Board study on double hulls.[15] A cost study was initiated, and the study paper results were used to update the costs for the PRA (see Appendix J for the full paper). The original RA costs for Rule I were used in a sensitivity case (Alternative Case 7) discussed in Chapter 9.

Rule VIII (Financial Responsibility)

The costs reported in the RA for Rule VIII (Financial Responsibility) were originally estimated by the National Pollution Funds Center (NPFC) in 1993, using a worst-case scenario. Actual industry experience during the subsequent 3.5 years provided the NPFC with information to better estimate costs in future years. NPFC took into consideration numerous factors, including annual premiums of commercial insurance guaranties, security bond guaranties, and costs to maintain a special-purpose corporation to act as financial guarantor. All costs associated with complying with the financial responsibility requirements of OPA 90 were estimated at

[15] *Double-Hull Tanker Legislation—An Assessment of the Oil Pollution Act of 1990*. Committee on Oil Pollution Act of 1990 (Section 4115) Implementation Review, Marine Board, Commission on Engineering and Technical Systems, National Research Council. 1998.

approximately $34 million for 1996. This value is down from $90 million during the first year. The actual cost dropped each year during this period because of increased competition and soft markets in the insurance and re-insurance communities.[16] Since these trends may not continue, the reference case assumes $34 million per year for the entire PRA assessment period. The original RA costs for Rule VIII were used in a sensitivity case (Alternative Case 7) discussed in Chapter 9.

Removing Spilled Oil from the Water

Rules that increase the quantity of spilled oil removed from the water before substantive damage occurs to the marine environment (within 72 hours) have costs associated with this removal above and beyond the compliance and enforcement costs described above. Four rules in the core group have an effect on fourth order events. Table 8-3 presents the four rules and the estimated effect on removing spilled oil from the water.

Table 8-3
Percent Increase in Baseline Spill Removal for Rules with Fourth Order Effectiveness (Removing Spilled Oil from the Water)

PRA Rule	Short Title	Tankers	Barges	Lightering	Facilities
III	Spill Source Control and Containment	2	2	3	3
IX	Vessel Response Plans	6	6	17	
X	Facility Response Plans				17
XI	PWS Equipment & Personnel Requirements	15			

Based on review of "The Financial Costs of Oil Spills," the PRA assumes that removing spilled oil costs $210 per barrel spilled.[17] The cost of removing spilled oil from the water is a relatively small portion of the cost of OPA 90. A sensitivity analysis in Chapter 9 (Alternative Case 4) demonstrates that changes in the removal cost assumed have little impact on PRA findings. Appendix G provides further detail on spill removal cost estimates.

Avoided Cost

Avoided costs are benefits measured in monetary terms rather than in barrels of oil. These benefits include reduced vessel damage, time lost for repairs, lost cargo, human injuries, and

[16] USCG internal memo, from Chief of the Vessel Certification Division, NPFC, to Chief of the Standards Evaluation and Analysis Division (G-MSR-1).

[17] Dagmar Schmidt Etkin, Ph.D., in *Oil Spill Intelligence Report*, Cutter Information Corporation, 1994. This is equivalent to $5 per gallon.

fatalities. Accident records from 1991–1990 provided historical data to develop the baseline avoidable costs for each spill source. The effectiveness factors for the first order events that contribute to avoided costs were applied to this baseline, and the stream of avoided costs was discounted to 1996 TPV. Table 8-4 presents effectiveness factors for first order events that result in avoided costs.

Table 8-4
Percent Decrease in Baseline Accidents for Rules with First Order Effectiveness (Casualties/Failures)

PRA Rule	Short Title	Tankers	Barges	Lightering	Facilities
III	Spill Source Control and Containment	1	3		
VI	Operational Measures for Single Hull Vessels	12	9		
VII	Licenses, Certificates, and Mariners' Documents	1	3		
VIII	Financial Responsibility	35	33	35	34

Table 8-5 presents yearly estimates of costs avoided as a result of OPA 90. While effectiveness factors were developed for lightering and facilities, accidents that result in vessel casualties or human losses are rare. The costs avoided, therefore, are $0. The costs for tankers and barges underway include vessel damage repair and time losses, human injuries and fatalities, and loss of oil shipments. Loss of oil shipments is the measuredbarrels of oil lost (spilled and not recovered) valued at $20 per barrel. Appendix H details the methodology for estimating avoided costs. Sensitivity analyses in Chapter 9 (Alternative Cases 8, 9, and 10) explore different assumptions for avoided costs.

Table 8-5
Avoided Costs ($1996) by Spill Source

Spill Source	Avoided Annual Costs
Tankers Underway	$78,752,736
Barges Underway	41,310,083
Lightering	0
Facilities	0

OPA 90 Core Group Assessment Period Cost

Total cost for each rule is the sum of compliance and enforcement costs and spill removal costs less avoided costs. Table 8-6 presents the total 1996 TPV of the 1996–2025 stream of costs for each of the 11 rules in the core group. OPA 90 is estimated to cost $10.6 billion TPV from 1996 through 2025, as measured using the core group of rules. Most of this cost is attributable to Rule I (Double Hulls) because of the large capital expenditures associated with this rule. Table 8-6 also presents the individual and marginal costs for each rule. The marginal and individual costs for spill removal and avoided costs differ because the overlapping effects of the rules, which

affect avoided costs, are accounted for in the marginal cost analysis. Correspondingly, the overall total cost is not the simple summation of the 11 rules, but is a value derived from PRAAM.

Table 8-6
Overall, Individual, and Marginal Costs of Core Group Rules for the Reference Case, in Order of Total Costs (Assessment Period 1996–2025, TPV, $1996)

PRA Rule	Short Title	Compliance and Enforcement	Spill Removal	(Avoided Costs)	Total
Overall Core Group Rule Costs		$11,270,221,620	$14,697,716	($714,321,518)	$10,570,597,818
Individual Rule Costs					
I	Double Hulls	$6,413,027,637	$0	($4,335,597)	$6,408,692,040
IX	Vessel Response Plans	3,245,869,985	19,015,482	(2,611,791)	3,262,273,676
XI	PWS E&P Requirements	324,803,281	1,699,769	(161,883)	326,341,168
III	Spill Source Control and Containment	216,146,138	7,426,169	(31,395,472)	192,176,835
V	Overfill Devices	182,784,171	0	(427,661)	182,356,509
X	Facility Response Plans	176,105,666	9,096,190	(2,777,912)	182,423,944
VI	Op. Measures for Single Hull Vessels	159,567,059	0	(91,338,213)	68,228,846
VII	Lic., Cert., and Mariners' Documents	80,125,189	0	(29,104,021)	51,021,168
II	Deck Spill Control	12,809,956	0	(29,004)	12,780,952
IV	Lightering of Single Hull Vessels	7,541,620	0	(331,915)	7,209,705
VIII	Financial Responsibility	451,440,918	0	(612,739,640)	(161,298,722)
Marginal Rule Costs					
I	Double Hulls	$6,413,027,637	$0	($1,883,431)	$6,411,144,206
IX	Vessel Response Plans	3,245,869,985	7,304,303	(1,006,241)	3,252,168,046
XI	PWS E&P Requirements	324,803,281	627,684	(59,779)	325,372,186
III	Spill Source Control and Containment	216,146,138	2,604,997	(18,570,641)	200,180,494
V	Overfill Devices	182,784,171	0	(125,738)	182,658,433
X	Facility Response Plans	176,105,666	3,853,233	(1,176,750)	178,782,149
VI	Op. Measures for Single Hull Vessels	159,567,059	0	(57,693,803)	101,873,256
VII	Lic., Cert., and Mariners' Documents	80,125,189	0	(17,701,501)	62,423,687
II	Deck Spill Control	12,809,956	0	(8,222)	12,801,735
IV	Lightering of Single Hull Vessels	7,541,620	0	(122,879)	7,418,741
VIII	Financial Responsibility	451,440,918	0	(557,201,356)	(105,760,438)

9. COST EFFECTIVENESS OF OPA 90

In this analysis, "cost effectiveness" is the 1996 TPV of the assessment period stream of costs (in 1996 constant dollar) divided by the 1996 TPV of the assessment period stream of benefits (in BNSR). The Volpe team estimated cost effectiveness for the reference case as well as ten alternative cases that test sensitivity to data and assumptions. The overall, marginal, and individual rule cost effectiveness estimates are presented below.

OPA 90 Core Group Assessment Period Cost Effectiveness

The reference case has the following parameters, prepared in collaboration with Expert Panel A (see Appendix C).

- Assessment period: 1996–2025
- Assessment period discount rate: 7 percent
- Bulk oil transport growth rate: 1 percent per year, 1996–2015
- Future oil spill rate derived past years: 1981–1990
- Pre-OPA 90 oil spill removal rate: 10 percent

In addition to these parameters, the reference case is defined by the effectiveness estimates (see Chapter 7) from Expert Panel B (Appendix C) that are then applied to baseline oil spill rates. Finally, the reference case uses the following cost estimates.

- Compliance and enforcement costs: Individual RAs, with exception of Rules I and VIII, where updated costs were used
- Value of barrel of oil spilled and removed: $210 per barrel
- Annual avoided costs per spill source ($1996): Tankers—$78,752,736/year
  Barges—$41,310,083/year
  Lightering operations—$0
  Facilities—$0
  Oil shipment loss—benefit barrels × $20 per barrel

Table 9-1 presents the overall, marginal, and individual rule cost effectiveness results for the reference case. Each rule's individual cost effectiveness is lower than its marginal cost effectiveness because while rule costs are approximately the same in the marginal and individual cases, the rule benefit is always smaller in the marginal case than in the individual case.[18]

Table 9-1
OPA 90 Core Group Cost Overall, Marginal, and Individual Rule Effectiveness ($/BNSR) for the Reference Case, in Order of Marginal Cost Effectiveness (TPV, $1996)

Overall Effectiveness: $8,657/BNSR			
PRA Rule	**Short Title**	**Marginal ($/BNSR)**	**Individual ($/BNSR)**
VIII	Financial Responsibility*	($201)	($189)
IV	Lightering of Single Hull Vessels	1,207	434
X	Facility Response Plans	3,039	1,313
III	Spill Source Control and Containment	3,492	1,243
VI	Operational Measures for Single Hull Vessels	3,687	981
VII	Licenses, Certificates, and Mariners' Documents	4,503	1,275
V	Overfill Devices	29,054	8,528
II	Deck Spill Control	31,141	8,813
IX	Vessel Response Plans	64,640	24,981
I	Double Hulls	68,079	29,563
XI	PWS Equipment & Personnel Requirements	108,857	40,318

*The negative values for Rule VIII result from avoided costs outweighing compliance and enforcement costs.

Sensitivity Analysis

The Volpe team analyzed ten alternative cases that tested ranges of values for several reference-case parameters. The alternative cases are as follows.

- **Alternative Case 1:** Bulk oil transport growth rate is 3 percent, 1996–2015 (reference case is 1 percent)
- **Alternative Case 2:** Future oil spill rate is the reference case × 0.5
- **Alternative Case 3:** Future oil spill rate is the reference case × 1.5
- **Alternative Case 4:** Value of barrel of oil spilled and removed is the reference case × 0.35

[18] The costs of compliance and enforcement are unchanged, but the avoided costs are assigned first order effectiveness factors for several rules, which may have overlapping effects that must be ascertained. Avoided costs, therefore, have an impact on marginal, but not individual, cost effectiveness values.

- **Alternative Case 5:** Costs of all rules × 1.5 and effectiveness factors of all rules × 0.5 (higher cost, lower effectiveness than reference case)

- **Alternative Case 6:** Costs of all rules × 0.5 and effectiveness factors of all rules × 1.5 (lower cost, higher effectiveness than reference case)

- **Alternative Case 7:** RA costs for Rules I (Double Hulls) and VIII (Financial Responsibility) (reference case uses updated costs)

- **Alternative Case 8:** Avoided costs are not included in cost estimates

- **Alternative Case 9:** Avoided costs are reference case × 0.5

- **Alternative Case 10:** Avoided costs are reference case × 1.5

Table 9-2 presents the results for the ten alternative cases and the reference case. Based on these results, several observations can be made—

- None of the alternative cases change the basic findings of the reference case—all the 11 core group rules contribute to the OPA 90 goal of reducing barrels of oil in the water.

- Rule VIII (Financial Responsibility) is the most cost effective (lowest cost per BNSR) except in Alternative Case 7.

- Rule XI (PWS Equipment and Personnel Requirements) is the least cost effective (highest cost per BNSR) in all alternative cases.

- No change in overall effectiveness is evident from Alternative Cases 8, 9, and 10.

- No shifts in rank order are observed in Alternative Cases 1, 2, and 3, and only minor shifts occur in Alternative Cases 4 and 5.

- Alternative Cases 6 and 7 show shifts in rank order. The most notable shift is in Alternative Case 7 where Rule VIII (Financial Responsibility) moves from first to sixth place.

- Changes in the marginal cost effectiveness of each rule follow those of overall cost effectiveness and the rank order of the rules remains approximately the same for most alternative cases.

Table 9-2
OPA 90 PRA Alternative Case Results, Overall and Marginal Cost Effectiveness for Alternatives Cases, in Order of Reference Case Marginal Cost Effectiveness ($/BNSR, TPV 1996)

PRA Rule	Short Title	Ref. Case	Alternative Case 1: 3% Traffic Growth per Year	2: Spill Rate × 0.5	3: Spill Rate × 1.5	4: Value Spill Removal × 0.35	5: Cost × 1.5, Eff. × 0.5	6: Cost × 0.5, Eff. × 1.5	7: RA Costs for I, VIII	8: No Avoided Costs	9: Avoided Costs × 0.5	10: Avoided Costs × 1.5
Overall Effectiveness (Percent)		67.1%	67.3%	67.1%	67.1%	64.7%	41.0%	83.1%	67.1%	67.1%	67.1%	67.1%
Overall Cost Effectiveness		$8,657	$6,993	$17,322	$7,527	$8,982	$22,214	$3,055	$10,323	$9,242	$8,949	$8,364
Marginal Cost Effectiveness												
VIII	Financial Responsibility	($201)	($342)	($383)	($178)	($188)	$1,093	($1,009)	$8,468	$859	$329	($732)
IV	Lightering of Single Hull Vessels	1,207	1,117	2,435	1,047	1,145	2,157	730	1,207	1,227	1,217	1,197
X	Facility Response Plans	3,039	2,463	6,032	2,648	3,696	5,152	1,878	3,039	3,059	3,049	3,029
III	Spill Source Control and Containment	3,492	2,924	6,959	3,040	3,841	6,374	1,957	3,492	3,816	3,654	3,330
VI	Op. Measures for Single Hull Vessels	3,687	3,113	7,394	3,204	3,493	8,926	723	3,687	5,775	4,731	2,643
VII	Lic., Cert., and Mariners' Documents	4,503	3,754	9,026	3,913	4,238	7,142	1,866	4,503	5,780	5,141	3,865
V	Overfill Devices	29,054	22,965	58,128	25,262	25,538	46,978	26,229	29,054	29,074	29,064	29,044
II	Deck Spill Control	31,141	24,607	62,303	27,077	27,373	48,631	23,854	31,141	31,161	31,151	31,131
IX	Vessel Response Plans	64,640	52,363	129,155	56,225	115,288	114,789	38,837	64,640	64,660	64,650	64,630
I	Double Hulls	68,079	52,975	136,179	59,197	64,672	129,241	40,479	41,320	68,099	68,089	68,069
XI	PWS E&P Requirements	108,857	104,301	217,524	94,683	296,035	171,647	66,411	108,857	108,877	108,867	108,847

- The absolute value of overall cost effectiveness improves with increased baseline spill quantities, whether from greater traffic growth (Alternative Case 1) or from increased spill rates (Alternative Case 3).

- The absolute value of overall cost effectiveness decreases if baseline future spill rates are lower (Alternative Case 2).

- The absolute value of overall cost effectiveness decreases slightly if barrels of spilled oil removed are valued less than barrels of oil not spilled (Alternative Case 4).

- Overall effectiveness changes significantly if rule effectiveness is estimated high (Alternative Case 5). Then, the overall effectiveness decreases dramatically.

- Overall effectiveness changes significantly if rule effectiveness is estimated low (Alternative Case 6). Then, the overall effectiveness increases dramatically.

- The absolute value of overall cost effectiveness decreases if RA reported costs are used for Rules I and VIII (Alternative Case 7).

- Avoided costs only slightly affect overall cost effectiveness of all the rules as a group and the marginal effectiveness of each rule, whether omitting them entirely (Alternative Case 8), decreasing them (Alternative Case 9), or increasing them (Alternative Case 10.)

- As would be expected, Rule VIII marginal cost effectiveness changes from a negative to a positive value when the avoided costs are reduced or eliminated.

Optimality of the Core Group of OPA 90 Rules

This PRA has presented the benefit, cost, and cost effectiveness of a core group of 11 rules within OPA 90. The Coast Guard performed additional analysis to assess the "optimality" of the core group of rules. This section shows the OPA 90 core group to be among 83 optimal combinations, given the more than 2,000 possible combinations of the 11 rules within the core group.

This PRA considered all 11 core group regulations together. There were, however, 2,047 possible combinations of these 11 rules. These combinations were modeled with PRAAM to estimate the potential benefits (measured in BNSR) and potential costs (measured in program costs less cost savings). We then compared the outputs of these 2,047 combinations to determine which of them produced optimal levels of benefits relative to costs.

When determining if any particular rule combination was optimal, we asked two questions—

1) Is there another rule combination that produces more benefit for the same cost?

2) Is there another rule combination that produces the same benefit for a lower cost?

If the answer to either question is affirmative, then the particular rule combination *was not optimal*. If the answer to either question is negative, we confirmed that we are estimating the greatest possible benefit for the lowest possible cost. This analysis found that 83 out of 2,047 rule combinations (4 percent) produced optimal results.

To determine this array of regulatory combinations that yielded optimal results, we first plotted the estimated benefits (BNSR) against the estimated costs ($1996, TPV) for 2,047 rule combinations. This plot is presented in Figure 9-1. As shown, there is a clear "clustering" of benefits and costs in these 2,047 rule combinations. From this analysis (and other analyses presented in this PRA), we determined that 3 of the 11 rules in the core group had a noticeable impact on benefits and costs—

- Rule I (Double Hulls)—inclusion in the rule combination resulted in significant costs but moderate benefits

- Rule VIII (Financial Responsibility)—inclusion in the rule combination resulted in significant benefits but moderate costs

- Rule IX (Vessel Response Plans)—inclusion in the rule combination resulted in significant costs but moderate benefits

Each "cluster" presented in Figure 9-1 was associated with one or more of these three rules. The vertical break represents the effects of Rule VIII. The horizontal breaks represent the effects of Rules I and IX. The details of the three rules included in each cluster are presented in Figure 9-2.

Figure 9-1
Benefits (Millions of BNSR) versus Costs ($Billions, 1996 TPV) for All 2,047 Combinations of OPA 90 Core Group Rules

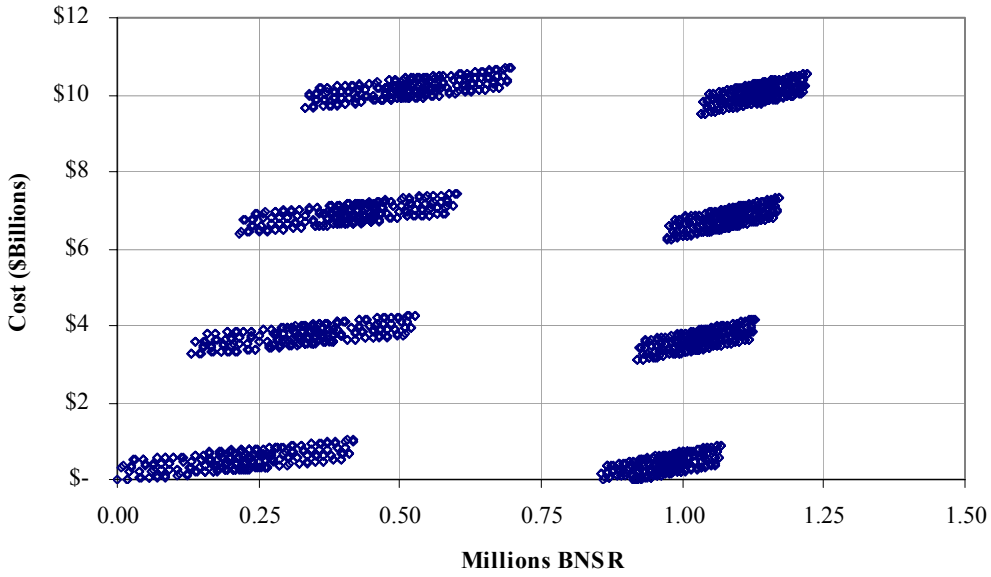
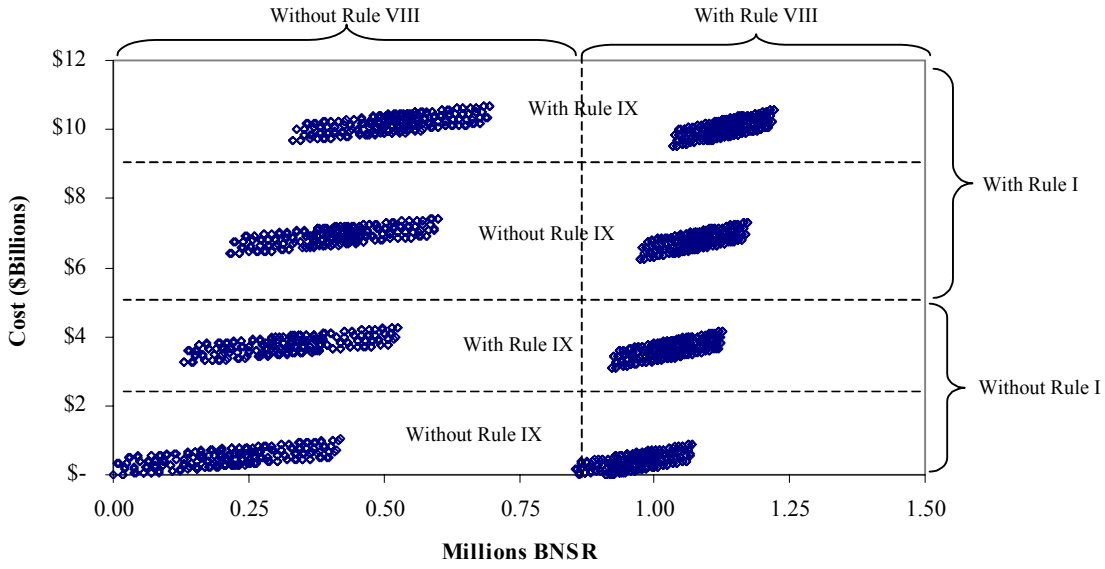


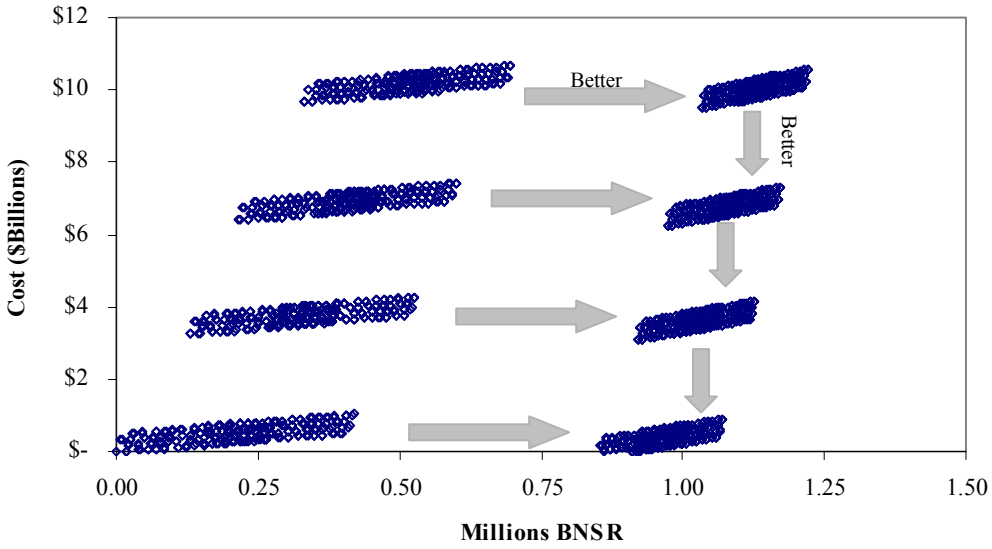
Figure 9-2
Details of Rules I, VIII, and IX for All 2,047 Combinations of OPA 90 Core Group Rules



After examining these plots, we made several preliminary observations. First, all combinations that did not include Rule VIII, which are in the four clusters on the left side of Figure 9-1, were suboptimal because there was a corresponding rule combination that included Rule VIII and that yielded in a substantially higher benefit. Additionally, most of the combinations in the clusters on

the right side were suboptimal because there were combinations that yielded the same benefits for a much lower cost. These relationships are presented in Figure 9-3.

Figure 9-3
Relationship of Suboptimal Rule Combinations to More Optimal Rule Combinations



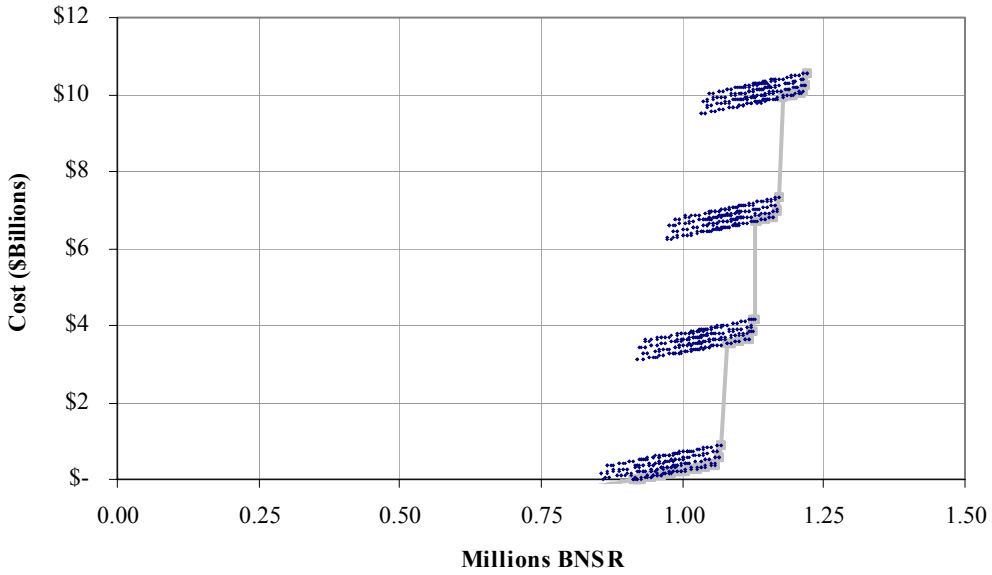
The rule combinations that did not include Rule VIII were suboptimal and could be eliminated from the analysis. The remaining 1,024 rule combinations were more optimal but most were still suboptimal and needed to be examined further. The next step was to determine which of the more-optimal rule combinations were actually optimal.

This determination was made in two ways: visually and mathematically. Visually, the optimal rule combinations are the bottom edges of each of the four clusters unless the cluster below contains a more optimal result. This relationship is presented in Figure 9-4. The gray line connects the optimal rule combinations and bridges the last optimal rule combination in a cluster to the first optimal rule combination in the higher cluster. Any of the rule combinations that did not fall on this line were not optimal because there was a rule combination that yielded more benefit with the same cost or the same benefit with a lower cost.

Mathematically, we determined the optimal rule combinations by first sorting the 1,024 combinations in ascending order of benefits. The rule combination with the highest benefit and corresponding lowest cost was the first optimal point, the rule combination with next-highest benefit and the next-lowest cost was the second optimal point, and so on. In other words, we created a set of points ranked by both *benefits* and *costs*, not just benefits. Rule combinations that could not be put into the ranking were eliminated because they were not optimal. Through this ranking, we determined that 83 rule combinations were optimal—they achieved the highest possible benefit for the lowest possible cost. These points are presented in Figure 9-5. When

compared to Figure 9-4, we can see that the 83 optimal rule combinations in Figure 9-5 constitute the line in Figure 9-4 without the segments that connect the clusters.

Figure 9-4
Optimal Combinations and Their Relationship to More Optimal Combinations, for 1,024 Rule Combinations



As presented in Figure 9-6, the 83 optimal points are connected to form the array of optimal rule combinations for the core group of OPA 90 rules. *All of the points along this line are optimal*—none of the points on the line is better or worse than any other point. Policy makers determine which point to choose along this line, taking into account financial, industry, and enforcement concerns as well as other policy issues. As long as policy makers select a rule combination that falls on this line, they are maximizing their benefit while minimizing their costs—i.e., *optimizing*.

The combination with all 11 core group rules, the subject of this PRA, fell on this line of optimal rule combinations (indicated in Figure 9-6). The 83 optimal rule combinations, along with their benefits and costs, are presented in Table 9-3. The PRAAM Run ID indicates whether or not a rule was included in the combination. A "1" indicates the rule was included; a "0" indicates the rule was not included (see Key below). Benefits and costs for all 2,047 rule combinations are presented in Appendix I.

Key to Example PRAAM Run ID

1	0	1	0	0	1	1	0	1	1	1
Rule I	Rule II	Rule III	Rule IV	Rule V	Rule VI	Rule VII	Rule VIII	Rule IX	Rule X	Rule XI

Figure 9-5
83 Optimal Combinations of OPA 90 Core Group Rules

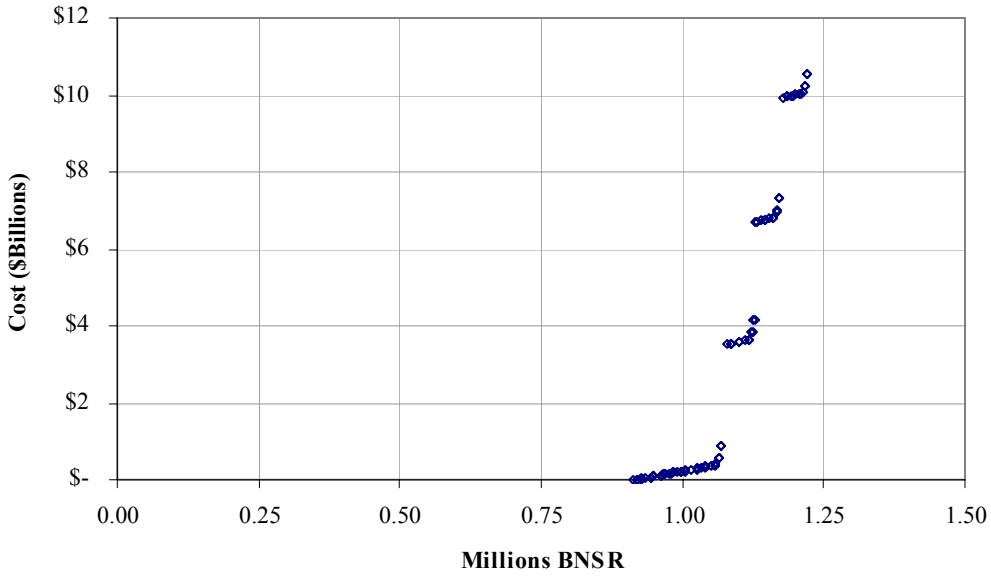


Figure 9-6
The Array of Optimal Combinations of OPA 90 Core Group Rules

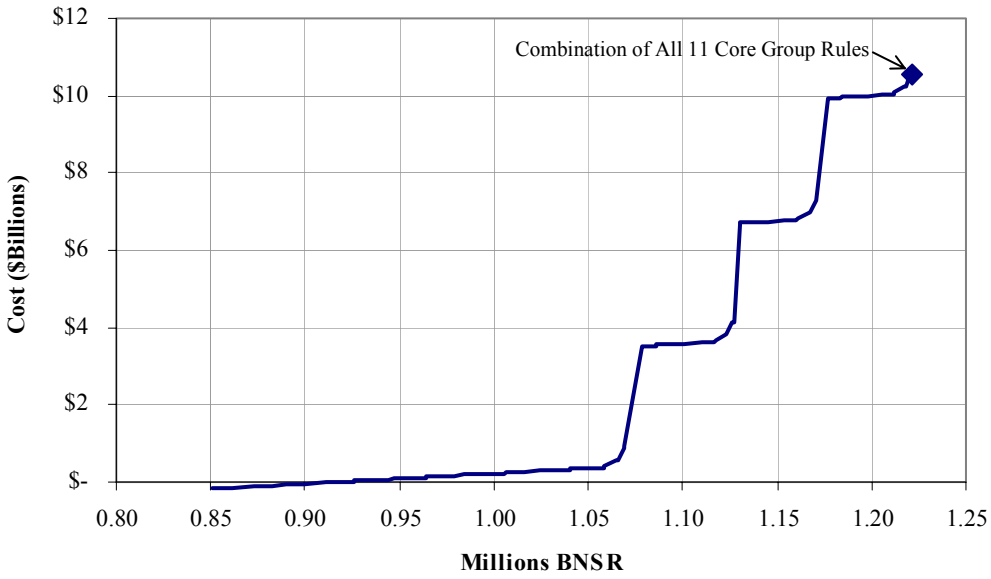


Table 9-3
83 Optimal Combinations of OPA 90 Rules and their Benefits (Millions BNSR), Costs ($ Millions, 1996 TPV), and Cost Effectiveness ($/BNSR)

PRAAM Run ID	Total Discounted Benefits (Millions BNSR)	Total Discounted Costs ($Millions, 1996 TPV)	Cost Effectiveness ($/BNSR)
00000001000	0.85	($161)	($189)
00010001000	0.86	(154)	(179)
01010001000	0.86	(141)	(164)
00000011000	0.87	(100)	(115)
00010011000	0.88	(93)	(105)
01010011000	0.88	(80)	(91)
00000101000	0.89	(61)	(69)
01000101000	0.89	(49)	(55)
01010101000	0.90	(41)	(46)
00000111000	0.91	0	0
00010111000	0.92	8	8
01010111000	0.92	21	22
00010001010	0.93	25	27
01010001010	0.93	38	41
00100001000	0.94	38	41
00110001000	0.94	46	48
01110001000	0.94	58	62
00010011010	0.95	86	91
01010011010	0.95	99	104
00110011000	0.96	107	111
01110011000	0.96	120	124
00010101010	0.96	125	130
01010101010	0.96	138	143
00100101000	0.97	139	143
00110101000	0.98	146	150
01110101000	0.98	159	163
00010111010	0.98	187	190
01010111010	0.98	200	203
00100111000	0.99	201	203
00110111000	1.00	209	209
00100001010	1.00	217	218
00110001010	1.01	224	223
01110001010	1.01	237	236
00100011010	1.02	278	274
00110011010	1.02	286	279
01110011010	1.03	298	291
00100101010	1.03	318	308
00110101010	1.04	325	313
01110101010	1.04	338	325
00100111010	1.05	380	362
00110111010	1.06	387	366

Table 9-3 (continued)
83 Optimal Combinations of OPA 90 Rules and Their Benefits (Millions BNSR), Costs ($ Millions, 1996 TPV), and Cost Effectiveness ($/BNSR)

PRAAM Run ID	Total Discounted Benefits (Millions BNSR)	Total Discounted Costs ($Millions, 1996 TPV)	Cost Effectiveness ($/BNSR)
01110111010	1.06	400	378
00111111010	1.07	570	535
01111111010	1.07	583	547
00111111011	1.07	895	838
01111111011	1.07	908	849
00100011110	1.08	3,532	3,276
00110011110	1.09	3,539	3,260
01110011110	1.09	3,552	3,270
00110101110	1.10	3,578	3,253
01110101110	1.10	3,591	3,263
00100111110	1.11	3,633	3,274
00110111110	1.12	3,640	3,260
01110111110	1.12	3,653	3,270
00111111110	1.12	3,823	3,404
01111111110	1.12	3,836	3,414
00111111111	1.13	4,148	3,683
01111111111	1.13	4,161	3,693
10110011010	1.13	6,696	5,925
11110011010	1.13	6,709	5,934
10100101010	1.14	6,728	5,912
10110101010	1.15	6,736	5,882
11110101010	1.15	6,748	5,891
10100111010	1.15	6,790	5,887
10110111010	1.16	6,798	5,859
11110111010	1.16	6,811	5,868
10111111010	1.17	6,980	5,981
11111111010	1.17	6,993	5,990
10111111011	1.17	7,306	6,243
11111111011	1.17	7,319	6,251
10100011110	1.18	9,941	8,448
10110011110	1.18	9,949	8,406
11110011110	1.18	9,961	8,414
10100101110	1.19	9,981	8,380
10110101110	1.20	9,988	8,342
11110101110	1.20	10,001	8,349
10100111110	1.21	10,043	8,333
10110111110	1.21	10,050	8,297
11110111110	1.21	10,063	8,304
10111111110	1.22	10,232	8,403
11111111110	1.22	10,245	8,411
10111111111	1.22	10,558	8,649
11111111111	1.22	10,571	8,657

OPA 90 PRA Findings

This PRA addresses two questions—

1) What is the overall benefit and overall cost effectiveness of a core group of Coast Guard regulations within OPA 90?

2) What is the relative contribution of each regulation to these overall values?

Both questions have been addressed in this PRA, but with differing levels of certainty. The overall benefit and cost effectiveness has been estimated in this section—a core group of 11 rules results in a 67 percent reduction in total oil spillage from 1996–2025. The analysis also estimates that overall cost effectiveness for the 30-year assessment period (1996–2025) is $8,657/BNSR (TPV in 1996 constant dollars). The overlapping effects of the core group of rules have been accounted for in these estimates; however, these overlapping effects make it difficult to isolate and estimate each regulation's net contribution of overall benefit. The second question, therefore, has been addressed indirectly by computing the marginal benefit of each rule—the incremental amount of the overall benefit that is contributed by an individual regulation.

To estimate the benefits of the core group of OPA 90 rules, the Volpe team developed a complex and robust accounting model (PRAAM) to ensure that the overlapping benefits of the rules were excluded from the analysis. Additionally, the Volpe team developed a methodology for analyzing the RAs for individual rules and converting all costs and benefits to 1996 TPV.

In 1992 the Coast Guard, in conjunction with OMB, identified "barrels of oil not spilled or spilled and removed from the water" (BNSR) as a measure of benefits, and "dollars per barrel of oil not spilled or spilled and removed" as a measure of cost effectiveness. These measures yield a common currency with which the Coast Guard expressed prospective effects of environmental measures without introducing uncertainties associated with assigning monetary values to environmental benefits on a national scale.

Cost-effectiveness values as reported in this PRA incorporate certain monetary benefits as avoided costs. To account for them, they are subtracted from compliance and enforcement costs because benefit is measured in barrels of oil rather than dollars. These avoided costs appear small, however, and have little effect on the relative merit of most rules as suggested by their respective marginal values.

This PRA aggregates and compliments the cost and benefit analyses in RAs for individual OPA 90 rules. Consistent with previous findings, this assessment concludes that while all OPA 90 rules reduce the total quantity of oil spilled by water transport systems, some rules have a greater effect than do others. For example, the rule establishing financial responsibility contributes

approximately 60 percent to the overall benefit (as measured in BNSR). Conversely, the rule for deck spill control contributes less than 1 percent to the overall benefit.

A sensitivity analysis of 10 alternative cases shows that when the core group of OPA 90 rules is ranked in order of their respective marginal cost effectiveness, uncertainties about key parameters have little effect on final results. The rank order of rules by their marginal values remains relatively constant among the alternative cases analyzed.

Finally, a Coast Guard analysis determines that 83 of the possible 2,047 combinations of the core group of rules are optimal—the combination maximizes possible benefit while minimizing possible costs. The combination of the 11 core group rules is one of these optimal points and maximizes the number of BNSR in a cost-effective manner.